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PART E RELIABILITY

VOYAGER CAPSULE PHASE B FINAL REPORT

VOLUME II CAPSULE BUS SYSTEM

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REPORT ORGANIZATION

VOYAGER PHASE B FINAL REPORT

The results of the Phase B Voyager Flight Capsule study are organized into several volumes. These are:

Volume I	Summary
Volume II	Capsule Bus System
Volume III	Surface Laboratory System
Volume IV	Entry Science Package
Volume V	System Interfaces
Volume VI	Implementation

This volume, Volume II, describes the McDonnell Douglas preferred design for the Capsule Bus System. It is arranged in 5 parts, A through E, and bound in 11 separate documents, as noted below.

Part A	Preferred Design Concept	2 documents, Parts A_1 and A_2
Part B	Alternatives, Analyses, Selection	5 documents, Parts B_1, B_2, B_3, B_4 and B_5
Part C	Subsystem Functional Descriptions	2 documents, Parts C_1 and C_2
Part D	Operational Support Equipment	1 document
Part E	Reliability	1 document

In order to assist the reader in finding specific material relating to the Capsule Bus System, Figure 1 cross indexes broadly selected subject matter, at the system and subsystem level, through all volumes.

VOLUME II CROSS REFERENCE INDEX

SYSTEM/SUBSYSTEM \ VOLUME II PARTS		PART A DESCRIPTION OF PREFERRED SYSTEM OBJECTIVES, MISSION, DESIGN, SUBSYSTEMS, OPERATIONS, SUPPORTING FUNCTIONS	PART B ALTERNATIVES, ANALYSIS AND SELECTION – METHODS TRADE STUDIES, OPTIMIZATION STUDIES RESULTS	PART C DETAILED DESCRIPTION OF SUBSYSTEM FUNCTIONS	PART D OPERATIONAL SUPPORT EQUIPMENT – SYSTEM, SUBSYSTEM, LAUNCH COMPLEX, MISSION, HANDLING, SOFTWARE	PART E RELIABILITY CONSTRAINTS, ANALYSIS, RESULTS, PROGRAM TESTING, CONTROL
CAPSULE BUS SYSTEM						
Mission	Objectives	1.1–Summary	2–Analysis	N/A	1–General	1–Constraints
	Profile	1.2–Summary	2–Analysis 2.4–Selection	N/A	N/A	3.1.1–Analysis
	Operations	4–Description by Phase	2.3–Analysis 2.3.7–Landing Site Select	N/A	4.4–LCE Description 4.5–MDE Description	3–Estimates
Design	General	2–Criteria Summary 3.1–Configuration	1–Study Approach 3–Functional Requirements	N/A	3.2–Concept 3.3–Summary 6.1–AHSE	4–Program Requirements 5–Component Reliability
	Standardization/Growth	2.5–Summary 11–Future	(See Specific Subsystem Below)	N/A	4.3.8-STC 4.4.8-LCE 4.5.8-MDE } Growth	N/A
	Weight	3.1.2.4–Summary 5–Breakdown	(See Specific Subsystem Below)	N/A	N/A	2.3.2–Reliability vs Weight
Interfaces (See Also Vol. V)		3.1–Summary 9.0–Operational	(See Volume V)	N/A	4.2.1,4.3.5,4.4.5, 4.5.5	N/A
Implementation (See Also Vol. VI)		10–Schedule 8.11–OSE	(See Volume VI)	N/A	(See Specific Subsystem Below)	N/A
Planetary Quarantine		7–General	(See Volume VI, C,7 Sterilization Plan)	N/A	None Required	N/A
O.S.E. (See Also Part D)		8–General (See Also–D1,D2, D3,D4)	(See D2.5-Selection Criteria, D9-Analysis, D10 - Alternatives)	(See D5-Subsystem Level Test Equipment, See Also D4, D6, D7)	Complete OSE Description	(See D4.3.6–STC D4.4.6–LCE D4.5.6–MDE)
SUBSYSTEMS						
Sterilization Canister		3.2.1.1–Description 3.1.2–Summary	5.1–Analysis	1.1	6.1.5.2,6.1.5.3, 6.1.5.6 6.1.5.8–AHSE 6.2.15–Servicing	(See Part C Sections 1.1.1.7 1.1.2.7 1.1.3.7)
Adapter		3.2.1.2–Description 3.1.2–Summary	5.2–Analysis	1.2	None Required	(See Part C, 1.2.7)
Aeroshell		3.2.1.3–Description 3.1.2–Summary	4.1–Configuration Selection	1.3	None Required	(See Part C, 1.3.7)

Figure 1

		4.6–Separation 5.3.1–Structure 5.3.2–Heat Shield			
Lander	3.2.1.4–Description 3.1.2–Summary	4.2–Configuration Selection 5.4–Analysis	1.4	6.1.5.9–Fixture	(See Part C, 1.4.7)
Telecommunications	3.2.2.1–Description	4.9–In-Flight Monitoring 5.5–Analysis	2–Telemetry 3–Radio 4–Antenna 5–Data Storage 6–Command	4.3.9.1–STC Console 5.7–Test Set	(See Part C, Sections 2.1.7, 2.2.7, 2.3.7, 3.1.7, 3.2.7, 4.5, 5.1.7, 5.2.7, 6.1.7, 6.2.7)
Power	3.2.2.2–Description	5.6–Analysis	7	4.3.9.1–STC Console 5.3–Test Set	(See Part C, Sect. 7.7)
Sequencing and Timing	3.2.2.3–Description	5.7–Analysis	8	4.3.9.1–STC Console 5.4–Test Set	(See Part C Sections 8.1.7, 8.2.7)
Guidance and Control	3.2.2.4–Description	4.7–De-orbit Attitube Reqm't. 5.8–Analysis	9	4.3.9.1–STC Console 5.5–Test Set	(See Part C, 9.7)
Radar	3.2.2.5–Description	5.9–Analysis	10	4.3.9.1–STC Console 5.6–Test Set	(See Part C, Sections 10.1.7, 10.2.7)
Aerodynamic Decelerator	3.2.3–Description	4.4–Selection 5.10–Analysis	11	None Required	(See Part C, 11.7)
Pyrotechnics	3.2.4–Description	5.11–Analysis	12	4.3.9.1–STC Console 5.9–Test Set	(See Part C, 12.7.1)
Thermal Control	3.2.5–Description	5.12–Analysis	13	4.3.9.1–STC Console 5.8–Test Set	(See Part C, 13.6)
De-orbit Propulsion	3.2.6.1–Description	5.13.1–Analysis	14	5.10–Test Set 6.1.5.10–AHSE	(See Part B, 5.13.4.5) (See Part C, 14.7)
Reaction Control	3.2.6.2–Description	5.13.2–Analysis	15	5.10–Test Set 6.2–Servicing	(See Part B, 5.13.4.5) (See Part C, 15.7)
Terminal Propulsion	3.2.6.3–Description	4.3–Configuration Selection 4.5–Terminal Deceleration 5.13.3–Analysis	16	4.3.9.1–STC Console 5.10–Test Set 6.2–Servicing	(See Part B, 5.13.4.5) (See Part C, 16.7)
Packaging and Cabling	3.2.7–Description	5.14–Analysis	17	4.3.9.8–Special Purpose Complex Equipment	Not Required

Note: Parentheses Refer Reader to Volumes/Parts Outside of the Respective Notation

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PART E

RELIABILITY

A summary of Engineering Reliability studies and results are contained herein. Significant attention was given to: 1) satisfying the constraints, 2) failure mode, effect and criticality analyses, 3) quantitative reliability estimates, 4) reliability program requirements and 5) component part reliability.

Reliability has been a key discipline in the VOYAGER system design for the development, integration, and selection processes of our preferred concept. "First time success" and capability for degraded mode operation were the key objectives that guided the reliability analyses. Each design concept was examined in detail to determine its contribution toward achieving these objectives. This was accomplished by utilizing four analytical and modeling techniques.

a) Failure Mode, Effect, and Criticality Analyses

b) Reliability-Weight-Effectiveness Analyses

c) Mission Effectiveness Model

d) Conceptual tradeoff studies

The most significant of these used by engineering reliability was the single-point failure modes, failure effects, and failure criticality analyses. With this technique, critical or potential single-point failure modes were identified early for the various engineering concepts. These analyses indicated the need for specific redundancies, so that no potential single failure mode could have a catastrophic effect on the mission, and to assure at least a degraded mode of operation.

The selection of the specific type of redundancy (functional, multi-channel, or block) was guided by the failure criticality of the mission event or equipment function. Incorporation of specific redundancies was influenced by the availability of a prime resource -- weight. The reliability-weight-effectiveness analyses resulted in the incorporation of redundancy in the most effective manner to meet the specific mission objectives. The probability of success for our Capsule Bus preferred concept is estimated at 0.830.

Recognition of equipment sensitivity to long-life storage (in transit) environment was taken into consideration in our design. Suggested design concepts were evaluated to assure their compatibility with the environments of decontamination, sterilization, and postulated Mars atmosphere and surface properties.

The study revealed that the following reliability program elements must receive increased major attention throughout the program:

a) Detail failure mode, effect, and criticality analyses

b) Specially planned parts and materials program

c) Positive failure evaluation and corrective action

d) Comprehensive design reviews

mitters of the Capsule Bus radio subsystem allows partial transmission and retrieval of Capsule Bus data. Specific design details are discussed within the functional descriptions of each subsystem.

SECTION 2

FAILURE MODE EFFECTS AND CRITICALITY ANALYSIS (FMECA)

Continual engineering reliability analyses were used in identifying and evaluating the failure modes and failure effects of the candidate concepts. Evaluation of the failure mode criticality led to redundancy considerations. These analyses identified the potential single point failure modes. The analyses also provided many design redundancy considerations which are tabulated in Figure 2-1.

2.1 FMECA METHOD - The method of performing the FMECA was to first identify the mission objectives:

a. Achievement of Flight Capsule landing
b. Performance of Entry Science experiments
c. Performance of Landed Science experiments
d. Measurement and transmission of engineering data

After identification of the mission objectives, the candidate concepts were evaluated by:

a. Identifying the major component or function
b. Identifying their failure modes
c. Classifying the effects of the failure modes

The depth of the analysis was confined to the detail of the design. In most cases design detail was available down to the component or function level. Figure 2.1-1 is a FMECA performed on the Capsule Bus sequencer and timer and is representative of the methodology used for all the subsystems. Other major subsystem FMECA's are presented within the subsystem functional descriptions, reference Part C of Volume II. The numbers in the failure category column classify the effects as:

(1) No effect on the mission objective.
(2) Degrading effect on mission objective.
(3) Possible catastrophic effect on mission objective.

Classifications 3-2, 2-1, 3-1, etc., indicate the limits over which the failure effect may vary, depending on the degree of failure or the time of occurrence in the mission.

2.2 FMECA RESULTS - Several failure modes, identified by the subsystem FMECA's, had significant effects on the achievement of the mission objectives. These modes are tabulated in the failure mode, effects, and criticality summary, Figure 2.2-1, along with the recommended solutions.

DESIGN CONCEPT REDUNDANCY CONSIDERATIONS

CAPSULE BUS FUNCTION OR EVENT	PRIMARY CONCEPT	REDUNDANCY CONSIDERATION	TYPE OF REDUNDANCY
Sense Capsule Altitude	Radar Altimeter Single transmitter tube	Provide two transmitter tubes with one acting as primary unit and second asbackup. Backup tube is operated when failure of primary tube is detected	Block
	Single receiver and tracker	Provide two receivers and trackers and logic for output control	Multi-channel
Sense Capsule Velocity	Three velocity receiving and tracking radar. Three channels required.	Provide four velocity receiving and tracking channels and logic to select any three of four for operation	Multi-channel
Regulate S/C Power Supplied to Capsule Bus	Single DC–DC converter regulator	Provide active redundant DC–DC converter regulator with broad regulation characteristics	Multi-channel
Provide Capsule Bus Power	Single battery	Sense low Capsule Bus battery voltage and switch to battery in surface laboratory	Block
Switch SLS Battery to Capsule Bus System	Single Relay	Provide active redundant relays with parallel contact arrangement	Multi-channel
Provide Battery Power to Solenoid and Pyrotechnic Devices	Two squib batteries both required	Provide three diode isolated batteries, any two of three required	Multi-channel
Transmit Capsule Bus Data from Separation to Landing	Capsule Bus Radio Link	Provide data interleaving between the Capsule Bus and Entry Science Package radio links	Functional
Monitor Capsule Bus System Status During Interplanatary Cruise	Cruise commutator and encoder	Provide standby cruise encoder. Provide series active redundant data switches and switch drivers	Block Multi-channel
Capsule Bus/Adapter Separation	Explosive bolts	Provide redundant cartridges in each bolt	Multi-channel
De-orbit Motor Release	Explosive bolts	Provide redundant cartridges in each bolt	Multi-channel
De-orbit Motor Separation	Springs	Provide redundant springs	Multi-channel
Canister Release	Shielded mild detonating cord (SMDC)	Provide redundant (SMDC)	Multi-channel
Canister Separation	Compression spring	Provide redundant compression springs	Multi-channel
Aeroshell Release	Explosive bolts	Provide redundant cartridges in each bolt	Multi-channel
Parachute Deployment	Parachute catapult	Provide redundant initiators in the catapult	Multi-channel
Parachute Disreefing	Lanyard actuated pyrotechnic reefing cutter	Provide (3) cutters for each line, one of three required	Multi-channel

Figure 2–1

Parachute Release	Explosive bolts	Provide redundant cartridges in each bolt	Multi-channel
Attitude Control	Monopropellant reaction control system, single ring	Redundant active ring Redundant components within the single ring	Multi-channel Multi-channel
De-orbit Propulsion	Single solid rocket motor	Redundant ignition	Multi-channel
Terminal Propulsion	4-Engine bi-propellent system	Redundant components within the propellant feed system Multiple engines (6) with engine out capability	Multi-channel Multi-channel
Initiated & Control Capsule Events	Sequencer & Timer (S & T)	Provide earth command back-up Redundant sequencer and timer Redundant circuitry with majority vote logic	Functional Block Multi-channel
Measure Capsule Acceleration	Single acceler ometer and associated electronics	Two accelerometers, select one prior to separation	Block
Inertial Sensing	3 orthorgonally mounted gyros	Redundant gyros, select one per pair prior to separation	Block
Guidance Computations	Single digital computer	Incorporate selected triple circuit redundancy with majority voting. Provide two memories, select one prior to separation	Multi-channel Block
Terminal Descent Control	Measured slant range from land-	Measured altitude from radar altimeter	Functional

Switch Flight Capsule to Internal Battery Power	Flight Spacecraft central computer and sequencer	Mission Operations System (MOS) command	Functional
Switch Flight Capsule to Flight Spacecraft Power	Flight Spacecraft central computer and sequencer	MOS Command	Functional
Turn on Capsule Bus Telemetry Subsystem	Capsule Bus test programmer	MOS Command	Functional
Turn on Entry Science Package Telemetry Subsystem	Capsule Bus test programmer	MOS Command	Functional
Switch Capsule Bus Telemetry Subsystem to Checkout Mode	Capsule Bus test programmer	MOS Command	Functional
Turn on Surface Laboratory Telemetry Subsystem	Capsule Bus test programmer	MOS Command	Functional
Turn on Surface Laboratory Test Programmer	Capsule Bus test programmer	MOS Command	Functional
Switch Capsule Bus Entry Science Package and Surface Laboratory to Internal Power	Capsule Bus sequencer and timer	Flight Spacecraft central computer and sequencer MOS Command	Functional

DESIGN CONCEPT REDUNDANCY CONSIDERATIONS (Continued)

CAPSULE BUS FUNCTION OR EVENT	PRIMARY CONCEPT	REDUNDANCY CONSIDERATIC	TYPE OF REDUNDANCY
Turn on Capsule Bus Guidance and Control System Inertial Measuring Unit	Capsule Bus sequencer and timer	MOS Command	Functional
Transfer Guidance Control System Data Words to Computer	Capsule Bus sequencer and timer	MOS Command	Functional
Activate Capsule Bus Squib Batteries	Capsule Bus sequencer and timer	MOS Command	Functional
Turn on Low-Rate UHF Transmitter	Capsule Bus sequencer and timer	MOS Command	Functional
Switch Capsule Bus Telemetry Subsystem to De-Orbit Mode	Capsule Bus sequencer and timer	MOS Command	Functional
Switch Flight Capsule Sterilization Canister to Internal Power	Capsule Bus sequencer and timer	MOS Command	Functional
Terminate Capsule Bus De-Orbit Motor Thrust	Capsule Bus guidance control computer	Capsule Bus sequencer and timer	Functional
Separate Spent Capsule Bus De-Orbit Motor	Capsule Bus pyrotechnic delay	Capsule Bus sequencer and timer	Functional
Turn on Capsule Bus Radar Altimeter	Capsule Bus sequencer and timer	.05 g Sensor	Functional
Initiate Descent TV Camera Sequencing	Capsule Bus sequencer and timer	.05 g Sensor Capsule Bus Radar Altimeter	Functional
Arm Terminal Propulsion System Pressurant and Isolation Valves	Capsule Bus sequencer and timer	Capsule Bus Radar Altimeter	Functional
Fire Terminal Propulsion System Pressurant Isolation Valves	Capsule Bus sequencer and timer	Capsule Bus Radar Altimeter	Functional
Fire Terminal Propulsion System Propellant Isolation Valves	Capsule Bus sequencer and timer	Capsule Bus Radar Altimeter	Functional
Turn on Capsule Bus Landing Radar	Capsule Bus radar altimeter	.05 g Sensor Capsule Bus integrated acceleration sensing	Functional

Figure 2-1 (Continued)

Update Capsule Bus Sequencer and Timer	Capsule Bus radar altimeter	Capsule Bus integrated [illegible] sensing	[illegible]
Enable Capsule Bus Aerodeceletator Deployment Mechanism	Capsule Bus sequencer and timer	Capsule Bus radar altimeter	Functional
Deploy Capsule Bus Aerodecelerator	Capsule Bus sequencer and timer	Capsule Bus radar altimeter	Functional
Arm Capsule Bus Aeroshell Separation Mechanism and Initiate Guidance Control Computer Descent Control Mode	Capsule Bus sequencer and timer	Capsule Bus radar altimeter	Functional
Release Capsule Bus Aero-shell from Capsule Bus (Electrical)	Capsule Bus sequencer and timer	Capsule Bus radar altimeter	Functional
Release Capsule Bus Aeroshell from Capsule Bus (Mechanical)	Capsule Bus sequencer and timer	Capsule Bus radar altimeter	Functional
Separate Capsule Bus Aeroshell from Capsule Bus and Switch Entry Science Package Telemetry Subsystem and Capsule Bus Telemetry Subsystem to Terminal Descent Mode	Capsule Bus sequencer and timer	Capsule Bus radar altimeter	Functional
Ignite Terminal Propulsion Motors	Capsule Bus radar altimeter	Capsule Bus landing radar	Functional
Release Capsule Bus Aerodecelerator from Capsule Bus	Capsule Bus sensor	Capsule Bus radar altimeter Capsule Bus sequencer and timer	Functional
Terminal Descent Control	Capsule Bus landing radar	Capsule Bus radar altimeter	Functional
Enable Capsule Bus and	Capsule Bus radar altimeter	Capsule Bus landing radar	Functional

Enable Capsule Bus and Surface Laboratory Impact Sensors and Release Descent TV Cameras	Capsule Bus radar altimeter	Capsule Bus landing radar	Functional
Terminate Capsule Bus Terminal Propulsion Motor Burn and Capsule Bus Attitude Control Electronics	Capsule Bus landing radar	Capsule Bus impact sensor Surface Laboratory impact sensor Capsule Bus sequencer and timer	Functional
Update Capsule Bus Sequencer and Timer (Time Update)	Capsule Bus impact sensor	Surface laboratory sequencer and timer	Functional
Arm Capsule Bus Stabilizer Legs	Capsule Bus sequencer and timer	Surface laboratory sequencer and timer	Functional
Release Capsule Bus Stabilizer Legs	Capsule Bus sequencer and timer	Surface laboratory sequencer and timer	Functional
Extend Capsule Bus Stabilizer Legs	Capsule Bus sequencer and timer	Surface laboratory sequencer and timer	Functional
Shut Down Entry Science Package	Capsule Bus sequencer and timer	Surface laboratory sequencer and timer	Functional
Switch Capsule Bus to Surface Laboratory Support Mode	Capsule Bus sequencer and timer	Surface laboratory sequencer and timer	Functional

D

FAILURE MODE, EFFECT AND CRITICALITY ANALYSIS
CAPSULE BUS SEQUENCER AND TIMER

FAILURE CATEGORY DEFINITION
1. No Effect on Mission Objective
2. Degrading Effect on Mission Objective
3. Possible Catastrophic Effect on Mission Objective

COMPONENT OR FUNCTION	FAILURE MODE	FAILURE EFFECT	FAILURE CATEGORY: Landing	Entry Science	Landed Science	Eng. Data	REMARKS
DC–DC Converter	No output	S&T fails to function	3	3	3	3	Prevents entire de-orbit sequence, etc. from occuring. Redundant regulators lower the probability of occurence best from effectiveness vs. weight standpoint.
Master Oscillator	No output	S&T fails to function	3	3	3	3	Prevents entire de-orbit sequence, etc. from occuring. Active redundant oscillators would prevent a single oscillator failure from causing S&T failure.
	Frequency instability	Inaccuracy in timing of functions	2	2	1	2	Adequate design should minimize this as a problem. (Mariner 4 had only slight drift.)
Reference Frequency Interface	No output	Fails to provide synch for using units	2	1	1	1	Design of using units will provide for free-running operation (unsynched) at frequencies slightly below the synch frequencies so that loss of synch only results in degraded operation.
Power Detector	Fails to detect power loss	Possible alteration of data in memory	3-2	3-2	3-1	3-1	When bias voltage is removed before logic voltage, a possibility exists that the memory will be altered by the shutfown transients. If significant digits are altered can cause events to occur too early or too late. Small probability of occurence.
	False Shutdown	Loss of down time in time count	1	1	1	1	No problem created if this occurs prior to final update. After that time only effect is a Δ delay in

B

Figure 2.1-1

							event times equal to the time during which power was lost.
Memory Buffer Register	Failure to allow data transfer from or to memory.	Loss of all functions other than as frequency generator for synch. use.	3	3	3	3	All data enters and leaves the memory buffer register. Loss of all or part of the memory buffer register can prevent all timed events from occuring. Duplexed memory registers used with the duplexing of memories would preclude this as a single point failure.
Decrementer and Zero Detector	Failure to decrement memory time word	All time functions fail to occur	3	3	3	3	All timed events are initiated by the DZD decrementing of the time word and detection of zero. Triple redundant decremeters and zero detectors with voters would reduce probability but already low probability of occurence.
	Failure to detect zero	No output discretes will occur	3	3	3	3	(Same as above)
Telemetry Interface	Failure to allow telemetry read-out of the S&T memory	Un certainty as to correctness of memory content	2-1	2-1	1	1	Failure to obtain telemetry read-out of the memory would necessitate either accepting the data already in the memory in an unverified state or attempting to write new words in the memory without being able to verify these words were correctly written into the memory. Redundant telemetry interface would reduce the probability of this occurence, however probability is already small.
Sensor Interface	Fails to recognize sensor acti-	Events timed from sensor occurence will fail to occur	3-2	3-2	3-2	3-2	All events which are timed from a sensor activation will fail to occur unless backup by some

	vation						other means exists. Redundant sensor interface would reduce the probability of this occurence however probability is already small.
	False indication that sensor has activated	Events timed from sensor occurence will occur at improper time	3-2	3-2	3-2	3-2	False indication might occur by virtue of a transient of by chatter in a relay acting as a sensor element. This failure mode requires triple redundant interface with majority voters to reduce likelihood of occurence.
Command Link Interface	Fails to allow memory up-date	Events will occur at nominal times programmed prior to command link interface failure.	2	2	1	1	Readout of memory during the test sequence will establish memory contents. If mission can be performed utilizing nominal times, separate command will be sent by MOS. Can be made redundant, however probability of failure is low.

A

FAILURE MODE, EFFECT AND CRITICALITY ANALYSIS
CAPSULE BUS SEQUENCER AND TIMER (Continued)

FAILURE CATEGORY DEFINITION
1. No Effect on Mission Objective
2. Degrading Effect on Mission Objective
3. Possible Catastrophic Effect on Mission Objective

COMPONENT OR FUNCTION	FAILURE MODE	FAILURE EFFECT	FAILURE CATEGORY: Landing	Entry Science	Landed Science	Eng. Data	REMARKS
Digital Data Interface	Fails to allow transfer of digital data words stored in S&T memory to using units.	Units will retain nominal words stored prior to failure and operate as for a nominal mission	3-2	3-2	3-1	3-1	Digital data interface can be made redundant, however, probability of failure is already low. Using units have pre-programmed nominal words and would operate on those words instead of allowing update.
Memory Drivers	Fail to drive.	Loss of row driven by failed driver	3-1	3-1	3-1	3-1	Criticality is based on which "bit" of time word failed by memory driver loss. Duplex of memories or programming of redundant time words in different "X" – "Y" locations would reduce the probability of this occurrence.
Memory Sense Amplifiers	Fail to perform sensing function.	Loss of memory plane associated with failed sense amplifier	3-1	3-1	3.1	3-1	Criticality is based on which "bit" of all time words is failed by memory sense amplifier loss. Triple redundant sense amplifiers with majority voter or duplex memory would reduce the probability of this occurrence.
Inhibit Drivers	Fails to drive	Loss of plane driven by failed inhibit driver	3-1	3-1	3-1	3-1	Criticality is based on which "bit" of time words may be incorrect. Duplexing of memories would reduce the probability of this failure mode.
Core Stack	Broken core	Loss of bit for storage purposes	3-2	3-2	3-1	3-1	Criticality dependent on word or "bit" associated with failure. Duplex memories would reduce the probability of

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Figure 2.1–1 (Continued)

							this failure mode, however probability of occurrence is extremely small.
	Broken drive, sense or inhibit functions associated with failed wire	Loss of drive, sense or inhibit functions associated with failed wire	3-2	3-2	3-1	3-1	Criticality dependent on word or "bit" associated with failure. Duplex memories would reduce the probability of this failure mode, however probability of occurrence is extremely small.
Discrete output drivers	Fails to actuate output	Loss of function controlled by output.	3-1	3-1	3-1	3-1	Criticality dependent on function controlled by output. Use of two outputs to actuate one function will prevent this from occurring.
	Fails to reset	Failure to turn off function controlled by output	3-1	3-1	3-1	3-1	Criticality dependent on function controlled by output. Triple redundant gates with majority voter would reduce the probability of this failure mode.
	False actuation	Enables function at improper time – possible mission abort	3-2	3-2	3-1	3-1	Criticality dependent on function controlled by output. Triple redundant gates with majority voter would reduce the probability of this failure mode.
Timing and Control Sensor Recognition	Fails to recognize sensor activation	Fails to command associated event at Δtime after sensor occurence.	3-2	3-2	3-1	3-1	All events which are timed from a sensor activation will fail to occur unless backup by some other means exists. Triple redundacizing of this function with majority voters will reduce probability of occurrence.
	False recognition of sensor	Commands associated event at Δtime after false sensor indication.	3-2	3-2	3-1	3-1	All events which are timed from the falsely recognized sensor activation will occur at the preprogrammed Δtime. Triple redundacizing of this function with

							majority voters will reduce probability of this failure mode.
Telemetry readout	Fails to transfer data from memory buffer register to telemetry interface	Failure to readout S&T memory content to MOS.	2-1	2-1	2-1	2-1	Failure to obtain telemetry readout of the memory would necessitate either accepting the data already in the memory in an unverified state or attempting to write new words in the memory without being able to verify these words were correctly written into the memory. Triple redundacizing of this function with majority voters would reduce probability of this failure mode.
Discrete Decoding	Failure to properly decode output address	Actuation of incorrect output and failure to actuate proper output when time word reaches zero.	3-2	3-2	3-1	3-1	Criticality is dependent upon function mistakenly activated and function not activated. Triple redundacizing of this function with majority voters would reduce the probability of this failure mode occurring.

A

FAILURE MODE, EFFECT AND CRITICALITY ANALYSIS
CAPSULE BUS SEQUENCER AND TIMER (Continued)

FAILURE CATEGORY DEFINITION
1. No Effect on Mission Objective
2. Degrading Effect on Mission Objective
3. Possible Catastrophic Effect on Mission Objective

COMPONENT OR FUNCTION	FAILURE MODE	FAILURE EFFECT	FAILURE CATEGORY: Landing	Entry Science	Landed Science	Eng. Data	REMARKS
Memory Driver Decoding	Failure to actuate proper "X" and "Y" memory drivers.	"Write" or "read" of data in incorrect memory location causing incorrect output and failure to actuate proper output when time word reaches zero.	3-2	3-2	3-1	3-1	Criticality is dependent upon function controlled by word mistakenly written. Triple redundacizing of this function with majority voters would re-reduce the probability of this failure mode occurring.
Frequency Dividers	Fails to divide	Probable failure of entire timing and control function	3-2	3-2	3-1	3-1	Prevents entire de-orbit sequence, etc., from occurring. Triple redundant frequency dividers with majority voters would reduce probability of this failure mode occurring.
Speed-Up Control	Fails to speed-up "clock" rate to compensate for time taken to read out telemetry.	Time error of time taken to read out memory	2-1	2-1	1	1	No problem created if this occurs prior to final update. After that time only effect is a Δ delay in event times equal to the time required to read out the memory. Triple redundant speed-up control with majority voters would reduce probability of this failure mode occurring.
External Clocking Gates	Fails to clock memory at externally supplied rate.	Either does not supply digital data to TM or using unit or supplies it at an unusable rate.	2-1	2-1	1	1	Memory cannot be read out and/or digital data cannot be transferred. Nominal times in S&T can be used or attempt made to read in new words without verification. Using units of digital words will use nominal data words. Triple redundant clocking gates

Figure 2.1-1 (Continued)

							would reduce probability, however probability is already small and does not warrant redundancy.
Bit Decoding	Incorrectly reads bit	Initiates Incorrect operation on word in memory buffer register	3-1	3-1	3-1	3-1	Criticality is dependent upon nature of operation initiated by the erroneous bit. Triple redundant bit decoding with majority voters would reduce probability of failure mode, however, probability of occurrence is low and redundancy is not warrented.
Address Decoding	Reads address location incorrectly	Initiates incorrect output when word decrements to zero	3-2	3-2	3-1	3-1	Criticality is dependent upon output incorrectly initiated. Triple redundant address decoders with majority voters would reduce probability of occurrence, however, probability of failure mode is small.
Address Comparator	Fails to correctly address words being inserted via command link or selects incorrect word for digital data read out.	Data words are read from or inserted into incorrect memory locations.	3-2	3-2	3-1	3-1	Criticality is dependent upon function controlled by memory location. Triple redundant address comparators would reduce probability of occurrence.
Command Link – Digital Data Register	Fails to allow the transfer of data from or to memory buffer register.	Fails to allow digital data readout causing those using units to use nominal pre-launch inserted data and fails to allow up-date of S&T memory causing discrete commands to occur at nominal pre-launch inserted times	2-1	2-1	1	1	Amount of degradation will depend on variation from nominal values. Triple redundant command link/digital data registers with majority voters would reduce probability of failure mode occurrence.

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS SUMMARY

COMPONENT OR FUNCTION	FAILURE MODE	FAILURE EFFECT	CRITICAL MISSION PHASE	RECOMMENDED REDUNDANCY CONSIDERATIONS
Guidance & Control				
Accelerometer	Degraded or no ouput	Loss of Capsule Control	Terminal Descent	• Provide two accelerometers select one during separation • Provide three accelerometers with majority rating.
Gyros	Degraded or no output	Loss of Capsule Control	Separation to Landing	• Redundant gyros, select one per pair prior to separation • 4 skewed gyros, select 3 prior to separation • 3 two degress of freedom gyros, two required
Landing Radar Velocity Sensor	Loss of velocity data	Loss of reference to velocity vector	Terminal Descent	• Provide 4 velocity channels three required. • Provide redundant transmitters • Provide redundant trackers in each velocity channel
Radar Altimeter	Loss of altitude data	Loss of altitude triggers and reference	Entry through terminal descent	• Provide redundnat transmitter • Provide redundant receivers and trackers
Guidance & Control Computer	Degraded or no output	Loss of guidance computations	Separation through terminal descent	• Provide redundant computers • Provide redundant memories • Provide triple redundant logic circuitry
Reaction Control System				
Pressurant Isolation Pyro Valve	Fail to fire or jams in closed position	Loss of Source Pressurant to system	Separation through terminal descent	• Provide redundant isolation valve
Pressurant Regulator	Fails closed	Propellant tank would not be pressurized	Separation through terminal descent	• Provide redundant regulator
Fuel Pressurization Pyro Valve	Fails closed or jams in closed position	Propellant tank will not be pressurized	Separation through terminal descent	• Provide redundant pyro valve
Fuel Isolation Pyro Valve	Fails to fire or jams in closed position	Loss of propellant source, engines would not fire	Separation through terminal descent	• Provide redundant fuel isolation valve.
Thrust Chamber Propellant Valves	Fails closed	Loss of propellant flow to the engines	Separation through terminal descent	• Provide quad redundant valves
Terminal Propulsion				
Pressurant Isolation Pyro...	Fail to fire or jams...	Loss of source...	Terminal descent	• Provide redundant...

Figure 2.2-1(Continued)

Valve	in closed position	pressurant to the system		isolation valve
Pressurant Regulator	Fails closed	Fuel and oxidizer tanks would not be pressurized	Terminal descent	• Provide redundant regulator
Fuel or Oxidizer Pressurization Pyro Valve	Fails to fire or jams in closed position	Fuel or oxidizer tanks would not be pressurized	Terminal descent	• Provide redundant pyro valve
Fuel Isolation Pyro Valve	Fails closed or jams in closed position	Loss of fuel supply to engines	Terminal descent	• Provide redundant valve
Oxidizer Isolation Pyro Valve	Fails closed or jams in closed position	Loss of oxidizer supply to engines	Terminal descent	• Provide redundant valve
Fuel or Oxidizer Engine Valves	Fails closed	Loss of fuel or oxidizer flow to the engines	Terminal descent	• Provide quad redundant valves
Throttling Mechanism Injector, Flow Control Valves and Actuator	Fails in deep throttle position or full thrust position	Capsule may impact at high velocity and random attitude	Terminal Descent	• Minimum redundancy can be provided by incorporating redundant drive motors in the actuator.
<u>De-Orbit Propulsion</u>				
Igniter Assembly	Fails to ignite or provide adequate thermal output	Propellent ignition failure with resultant loss of thrust	De-orbit Maneuver	• Provide dual initiators
Rocket Motor	Failure of propellant to ignite	Motor fails to provide thrust for de-orbit maneuver	De-orbit maneuver	• Remote failure mode No redundancy consideration
<u>De-Orbit Motor Release and Separation</u>				
Explosive Bolt	Fails to break when fired (Any one of four)	De-orbit motor will not separate	Entry through terminal descent	• Provide dual cartridges in each bolt with either providing adequate energy to break the bolt.
Electrical Disconnect	Fails to disengage	Incomplete separation	Entry through	• Provide dual cartridges either

(Pyro Spin Off)		of de-orbit motor	terminal descent	providing adequate energy. ● Provide lanyard back-up.
Parachute Release				
Explosive Bolt	Fails to break when fired(any one of four)	Parachute, catapult and support structure will not separate	Entry through terminal descent	● Provide dual cartridges in each bolt with either providing adequate energy to break bolt
Electrical Disconnect (Pyro spin off)	Fails to disengage	Parachute, catapult and support structure will not separate unless chute drag force is sufficient to effect separation	Entry through terminal descent	● Provide dual cartridges either providing adequate energy. ● Provide Lanyard back-up.
Adapter/Capsule Bus Separation				
Explosive Bolt	Fails to break when fired (Any one of eight)	Capsule will not separate from the adapter	Separation	● Provide dual cartridges either providing adequate energy.

D

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS SUMMARY (CONTINUED)

COMPONENT OR FUNCTION	FAILURE MODE	FAILURE EFFECT	CRITICAL MISSION PHASE	RECOMMENDED REDUNDANCY CONSIDERATIONS
Canister Release				
Shielded Mild Detonating Cord Assembly (SMDC)	Fails to ignite or propogate	Canister fails to separate	Separation	• Provide two redundant assemblies with redundant igniter in each assembly
Lander/Aeroshell Release				
Explosive Bolt	Fails to break (Any one of four)	Aeroshell will not separate	Entry through terminal descent	• Provide dual cartridges either providing adequate energy.
Electrical Disconnect (Pyro Spin Off)	Fails to disengage	Incomplete separation of aeroshell from lander	Entry through terminal descent	• Provide dual cartridges either providing adequate energy. • Provide lanyard back-up
Aerodynamic Decelerator				
Parachute Catapult Assembly	Output charge fails to ignite	Parachute will not be deployed	Entry	• Provide redundant initiators
Parachute Assembly	Fail to disreef	Lander may impact at destructive velocity	Entry	• Provide redundant reefing cutters (one of three required)
Electrical Power				
DC-DC Converter Regulator	Short, open, or loss of regulation	Loss of S/C supplied power regulation	Interplanetary cruise	• Provide active redundant regulator with broad regulation characteristics
Main Battery	Degraded or no output	Minimum or no power to Capsule Bus systems	Separation to landing	• Provide redundant battery • Provide backup capability by using surface lab power.
Squib Battery 1 or 2	Degraded or no output	Minimum or no power to squib and solenoid functions	Separation to landing	• Provide redundant battery and incorporate diode isolation so that only 2 of 3 required.
Sequencer & Timer				
DC-DC Converter	No output	S & T fails to function	Separation through landing	• Provide redundant DC-DC converter
Master Oscillator	No output	S & T fails to function	Separation through landing	• Provide active redundant oscillators
Memory Buffer Register	Failure to allow data transfer to or from memory	Loss of all functions other than frequency generator	Separation through landing	• Provide duplexed memories and registers
Decrementers and Zero Detectors	Failure to decrement memory time-word	All time functions fail to occur	Separation through landing	• Provide triple redundant decrementer with majority voter
	Failure to detect zero	No output discretes will	Separation through	• Provide triple redundant zero

Figure 2.2-1 (Continued)

Frequency Dividers	Fails to divide	Probable failure of entire timing and control function	Separation through landing	• Provide triple redundant frequency divider s with majority voter
Telecommunications				
Cruise Commutator and Primary Commutator	Group, subgroup, or individual data channel inoperative	Partial loss of engineering data	Interplanetary cruise through landing	• Provide series active redundant data switches and switch drivers
Cruise Encoder and Primary Encoder	Inoperative or digital bit errors	Loss of all engineering data if inoperative	Interplanetary cruise through landing	• Provide standby redundant encoder to be switched by earth command.
Programmer	Inoperative or partial loss of sequencing and control	Loss of all engineering data if inoperative	Separation through landing	• Provide decentralization of sequencing and control functikns for minimum failure effect.
Clock Generator	Inoperative or unstable	Loss of all engineering data if inoperative	Separation through landing	• Provide redundant temperature compensated clock generator crystals
Telemetry Power Supply	Inoperative or degraded output	Loss of all engineering data if inoperative	Seperation through landing	• Provide active redundant load sharing circuit components.
Adapter Cruise Commutator and Encoder	Inoperative commutator group, subgroup, or individual data channels. Inoperative encoder or digital bit errors	Loss of adapter status monitoring throughout cruise phase	Interplanetary cruise	• Provide series active redundant data switches and switch drivers. • Provide standby redundant enccder to be switched by earth command
RT DT Data Interleaver	No output or data mixing	Possible loss of black out data	Entry and Descent	• Provide series active redundant interleaver switches. • Interleave data with ESP radio link
CBS Data Interleaver	No output or data mixing	Loss of engineer ing data	Separation through landing	• Interleave capsule data on ESP radio link • Provide series active redundant interleaver switching.
S/C Mounted Data Distribution Unit	Inoperative or steering logic errors	Loss of flight capsule data	Interplanetary cruise through landing	• Provide active redundant data switches and switch drivers.
Low Rate UHF Transmitter	Degraded or no power output	Loss of CBS Engineering data	Entry to landing	• Provide redundant transmitter • Interleave data on ESP radio link
S C Mounted UHF Radio Receiver	Inoperative or poor sensitivity	Loss of CBS Engineering data	Entry to landing	• Provide Redundant receivers • Interleave data on ESP radio link
Delay Storage	Inoperative or erroneous output	Loss of engineering data during blackout	Entry	• Interleave data on ESP radio link
S C Mounted Tape Storage	Inoperative in record or playback mode	Loss of engineering data	Separation to landing	• Interleave data on ESP radio link

2.3 REDUNDANCY - Redundancy was necessary to meet the criterion that no potential single failure mode shall cause a catastrophic effect on the mission, and also to assure a high level of success in achieving the mission objectives. An initial prime requirement for the Flight Capsule design was to find an optimum breakdown, arrangement, or interlacing of subsystems. By such means it was desired to have a number of subsystems provide backup to other subsystems to achieve functional redundancy. Such benefit, although in degraded mode, is accomplished without the expense of added weight. This approach is not based on equipment duplication but rather upon being able to accomplish the function in an alternate manner. As a result, functional redundancy is our preferred approach, wherever practical. Three types of redundancies were considered and criteria for effective allocation of these redundancies was developed.

2.3.1 Types of Redundancies - Three redundancy schemes were studied and utilized in the system design. Each type of redundancy has its particular advantages. The decision to use one or another required careful consideration of the particular application and its possible consequences.

a. Alternate Path or Functional Redundancy Method - This redundancy is characterized by providing two or more physically different but functionally identical methods to accomplish a function. The prime objective in employing this method is to provide at least two separate and independent paths by which critical operations may be performed. This type is the preferred choice because it offers greater protection against generic failure modes and unknown environmental stresses. It can be designed into the system at relatively low penalties in terms of weight, volume, power, and system complexity.

b. Cooperative Multi-channel Methods - This redundancy is characterized by dividing the equipment for performing the function into two or more independent portions in such a manner that some portion can fail and the function can still be performed with minimum or no degradation. This type is the next choice because no failure detection or switching features are required with this method. It is normally designed into the system at a moderate penalty in weight, volume, and power.

c. Ordinary Block or Element Redundancy Method - This redundancy is characterized by the paralleling of two identical units in which failure of the operating unit is sensed and identical equipment is switched in to accomplish the function. This type is the least desirable because both units are susceptible to the same failure modes if exposed to overstressed conditions. It also requires the addition of a detection and switching unit, therefore providing the least overall reliability improvement. In addition parallel units with a detection and switching unit more than doubles the weight and increases power requirements.

2.3.2 Reliability Versus Weight - The FMECA led to many suggested possibilities for the incorporation of redundancies. However, the addition of redundancies represents a corresponding weight increase. Thus, an initial criterion for decisions on redundancy incorporation needed to be established. This criterion was a requirement for achieving maximum increase in reliability with a minimum weight increase. An illustration of the implementation of this criterion is shown in Figure 2.3.2-1. The failure rate (λ) for each component, system or subsystem must be utilized in establishing the non-redundant reliability (R_o) from the equation:

$$R_o = e^{-\lambda t}; \quad (\ln R_o = -\lambda t)$$

Then the reliability improvement for each subsequent change ($\Delta \ln R$) was calculated by:

$$R_i = e^{\ln R_o + \Delta \ln R}; \quad \Delta \ln R = \ln R_i - \ln R_o$$

Preference was given the component with the lowest weight increase for an incremental change in reliability ($\Delta W/\Delta \ln R$) followed by units of increasing $\Delta W/\Delta \ln R$. Utilization of this criterion resulted in the redundancy considerations shown in Figure 2.3.2-2 and indicated the potential reliability improvement as shown in Figure 2.3.2-3. This technique of redundancy considerations was applied to the Capsule Bus, and placed equal emphasis on the achievement of each mission objective. The competing characteristics of the Performance and Design Requirements for the 1973 Mission indicates that equal emphasis should not be placed on each mission objective. Therefore, an additional analytical technique was needed based on the priority of these objectives. Fulfillment of this need was accomplished by an effectiveness analysis study for the redundancy considerations.

2.3.3 Effectiveness Analysis - The effectiveness analysis study is the adaptation of a technique which evaluated the redundancy in terms of achievement of the mission objective. The equation developed was:

$$E = V_1R_1 + V_2R_2 + V_3R_3$$

where V_1 = Value index for the achievment of landing

V_2 = Value index for the performance of Entry Science experiments

GUIDANCE AND CONTROL RELIABILITY VS. WEIGHT

COMPONENT	BASELINE				ALTERNATE					
	(1) tm	(2) λ	(3) $-\ln R \times 10^6$	W (lbs)	(4) $-\ln R \times 10^6$	(4) W (lbs)	$\Delta \ln R \times 10^6$	ΔW (lbs)	$\Delta W / \Delta \ln R$	Changes
Intertial Measuring Unit				14						
Rate Integrating Gyro	94	120	11,280		1,228	–	13,790	3.87	281	G1
Gyro Electronics	94	27	2,738		↓		↓	↓	↓	
Accelerometer	94	20	1,880		210	–	2,892	2.8	965	G2
Accelerometer Electronics	94	13	1,222		↓		↓	↓	↓	
0.05g Switch	94	—	100	↓	<1	2.8	100	2.1	21,000	G7
Power Supply	94	13	1,222	7	284	14.5	938	7.5	7,996	G6
G & C Computer	87	135	11,745	16	1,155	32.5	10,590	16.5	1,558	G3
Radar Altimeter	87	190(5)	2,324(6)	23	684	20.8	1,640	3.8	2,317	G5
Landing Radar	87	274(5)	14,795(7)	40	10,435	48.52	4,360	8.52	1,954	G4

(1) Modifying Time Factor X Time (Hours)

(2) λ = Failures Per Million Hours

(3) $-\ln R \times 10^6 = tm\ \lambda$

(4) Computed lnR and Weight Based on Added Redundancy

(5) Failure Rate Considering all Parts in Series

(6) Redundancy Included in Baseline Radar Altimeter. One of Two Transmitter Tubes and One of Two Receivers and Trackers Required.

(7) Redundancy Included in Baseline Landing Radar. Three of Four Velocity Channels Including Antenna, Mixer, AF Amplifier and Tracker Required.

Configuration*	ΔW (lbs)	$\Sigma\Delta$W (lbs)	$\Delta \ln R \times 10^6$	$\Sigma \ln R \times 10^6$
Baseline	—	0	—	47,270
G1	3.87	3.87	13,790	33,480
G2	2.8	6.67	2,892	30,588
G3	16.5	23.17	10,590	19,998
G4	8.52	31.69	4,360	15,638
G5	3.8	35.49	1,640	13,998
G6	7.5	42.99	938	13,060
G7	2.1	45.09	100	12,960

* Changes G1, G2, etc., to the Baseline Subsystem are Cumulative.

G1 – Multi Axis Gyro Sensing.

G2 – One of Two Accelerometers and Electronics Selected During In-Flight Checkout.

G3 – One of Two Guidance and Control Computers Selected During In-Flight Checkout.

G4 – Redundancies Added to Baseline Landing Radar Provide One of Two Velocity Sensor Transmitters, One of Two Range Sensor Transmitters and Modulators and One of Two Range Sensor Preamp and Tracker Channels Which are Selected During In-Flight Checkout.

G5 – Baseline Radar Altimeter Redundancy Changed to Provide One of Two Altimeter Electronics Which is Selected During In-Flight Checkout.

G6 – Active Redundant Power Supplies.

G7 – Quad Redundant 0.05g Switches.

Figure 2.3.2–1 (Continued)

CAPSULE BUS REDUNDANCY CONSIDERATIONS
(RELIABILITY vs. WEIGHT)

ORDER OF PRIORITY	REDUNDANCY CONSIDERATION	SUBSYSTEM	TYPE
1	Standby Redundant Cruise Encoder	Telecommunications	Block
2	Series Activity Redundant Cruise Commutator, Data Switches and Switch Drivers	Telecommunications	Multi-channel
3	Interleaver Low Rate Data on ESP Radio Link	Telecommunications	Functional
4	Series Active Redundant Cruise Monitor Control, Data Switches and Switch Drivers	Telecommunications	Multi-channel
5	Series Active Redundant Adapter Cruise Commutator, Data Switches, Switch Drivers and Redundant Cruise Encoder	Telecommunications	Multi-channel & Block
6	Surface Laboratoty Power Provide Backup to Capsule Bus Power	Electrical Power	Block
7	Active Redundant DC–DC Converter Regulator	Electrical Power	Multi-channel
8	Standby Redundant Battery Float Chargers	Electrical Power	Block
9	Active Redundant Reefing Cutters for Each Reefing Line	Staging	Multi-channel
10	Standby Redundant CBS Commutator and Encoder	Telecommunications	Block
11	Multi-axis Gyro Sensing	Guidance & Control	Block
12	Active Redundant Cruise Commutator Relays	Electrical Power	Multi-channel
13	Active Redundant Command Decoder Relays	Electrical Power	Multi-channel
14	Active Redundant Battery Charger Relays	Electrical Power	Multi-channel
15	Standby Redundant Programmer	Telecommunications	Block
16	Redundant Velocity Channel in Landing Radar	Guidance & Control	Multi-channel
17	Standby Redundant Guidance and Control Computers	Guidance & Control	Block
18	Active Redundant Receivers and Trackers in Radar Altimeter	Guidance & Control	Multi-channel
19	Active Redundant Thermostats for Heater Control	Thermal Control	Multi-channel

Figure 2.3.2-2

20	Dual Cartridge Explosive Bolts for Capsule Bus/Adapter Separation	Staging	Multi-channel
21	Standby Redundant Accelerometers and Associated Electronics	Guidance & Control	Block
22	Active Redundant Crystal Controlled Oscillators	Sequencer & Timer	Multi-channel
23	Dual Cartridge Explosive Bolts for De-orbit Motor Release	Staging	Multi-channel
24	Dual Cartridge Explosive Bolts for Aeroshell Release	Staging	Multi-channel
25	Redundant Cartridge in Each of Three NC Reaction Control System Pyro Valves	Propulsion	Multi-channel
26	Redundant Initiators in, Parachute Catapult	Staging	Multi-channel
27	Duplex Memories and Memory Buffer Registers With Error Detection Switching Logic	Sequencer & Timer	Block
28	Triple Redundant Frequency Dividers With Majority Voters	Sequencer & Timer	Multi-channel
29	Dual Cartridge Explosive Bolts for Parachute Release	Staging	Multi-channel
30	Active Redundant (Load Sharing) Telemetry Power Supply	Telecommunications	Multi-channel
31	Series Redundant Pressure Regulator in the Reaction Control System	Propulsion	Multi-channel
32	Standby Redundant Transmitter Tubes in the Radar Altimeter	Guidance & Control	Block

CAPSULE BUS REDUNDANCY CONSIDERATIONS (Continued)
RELIABILITY VS. WEIGHT

ORDER OF PRIORITY	REDUNDANCY CONSIDERATION	SUBSYSTEM	TYPE
33	Active Redundant Resistance Heaters	Thermal Control	Multi-channel
34	Dual Cartridges Explosive Bolts for Release of Stabilizer Legs	Landing	Multi-channel
35	Triple Redundant Decrementers and Zero Detectors With Majority Voters	Sequencer & Timer	Multi-channel
36	Added Element Redundancy to the Landing Radar	Guidance & Control	Block
37	Active Redundant Discrete Output Line Drivers	Sequencer & Timer	Multi-channel
38	Redundant Cartridge in Each of Three NC Terminal Propulsion System Pyro Valves	Propulsion	Multi-channel
39	Triple Redundant Control Logic With Majority Voters	Sequencer & Timer	Multi-channel
40	Quad Redundant Input Power Diodes	Electrical Power	Multi-channel
41	Active Redundant Sensor Interfaces	Sequencer & Timer	Multi-channel
42	Active Redundant Telemetry, Command Link, Reference Frequency and Digital Data Interfaces	Sequencer & Timer	Multi-channel
43	Series Redundant Pressure Regulator in the Terminal Propulsion System	Propulsion	Multi-channel
44	Triple Redundant Discrete Output Gates With Majority Voters	Sequencer & Timer	Multi-channel
45	Active Redundant Bias Voltage and Logic Voltage Regulators	Sequencer & Timer	Multi-channel
46	Redundant Cartridge in Each of Two NO Terminal Propulsion System Pyro Valves	Propulsion	Multi-channel

Figure 2.3.

47	Redundant Springs for De-orbit Motor Separation	Staging	Multi-channel
48	Active Redundant Battery Power Distribution Relays	Electrical Power	Multi-channel
49	Active Redundant Subsystem Control Relays	Electrical Power	Multi-channel
50	Redundant Reaction Control System Pressurant Supply	Propulsion	Multi-channel
51	Active Redundant Guidance and Control System Power Supplies	Guidance & Control	Multi-channel
52	Redundant Check Valves in the Terminal Propulsion System	Propulsion	Multi-channel
53	Quad Redundant Reaction Control System Thrust Chamber Propellant Valves	Propulsion	Multi-channel
54	Redundant Shielded Mild Detonating Cord Assembly for Canister Release	Staging	Multi-channel
55	Redundant Compression Spring for Canister Separation	Staging	Multi-channel
56	Active Redundant Heater Relays (Post Separation)	Electrical Power	Multi-channel
57	Active Redundant Heater Relays (Pre Separation)	Electrical Power	Multi-channel
58	Active Redundant Master Test Programmer Relays	Electrical Power	Multi-channel
59	Quad Redundant 0.05g Switches	Guidance & Control	Multi-channel
60	Parallel Redundant Engine Valves in the Terminal Propulsion System	Propulsion	Multi-channel
61	Active Redundant Squib Batteries	Electrical Power	Multi-channel
62	Active Redundant Main Bettery	Electrical Power	Multi-channel
63	Quad Redundant Battery Power Diodes	Electrical Power	Multi-channel
64	Quad Redundant Squib Battery Diodes	Electrical Power	Multi-channel

-2(Continued)

CAPSULE BUS
RELIABILITY IMPROVEMENT VS. ADDED REDUNDANCY WEIGHT

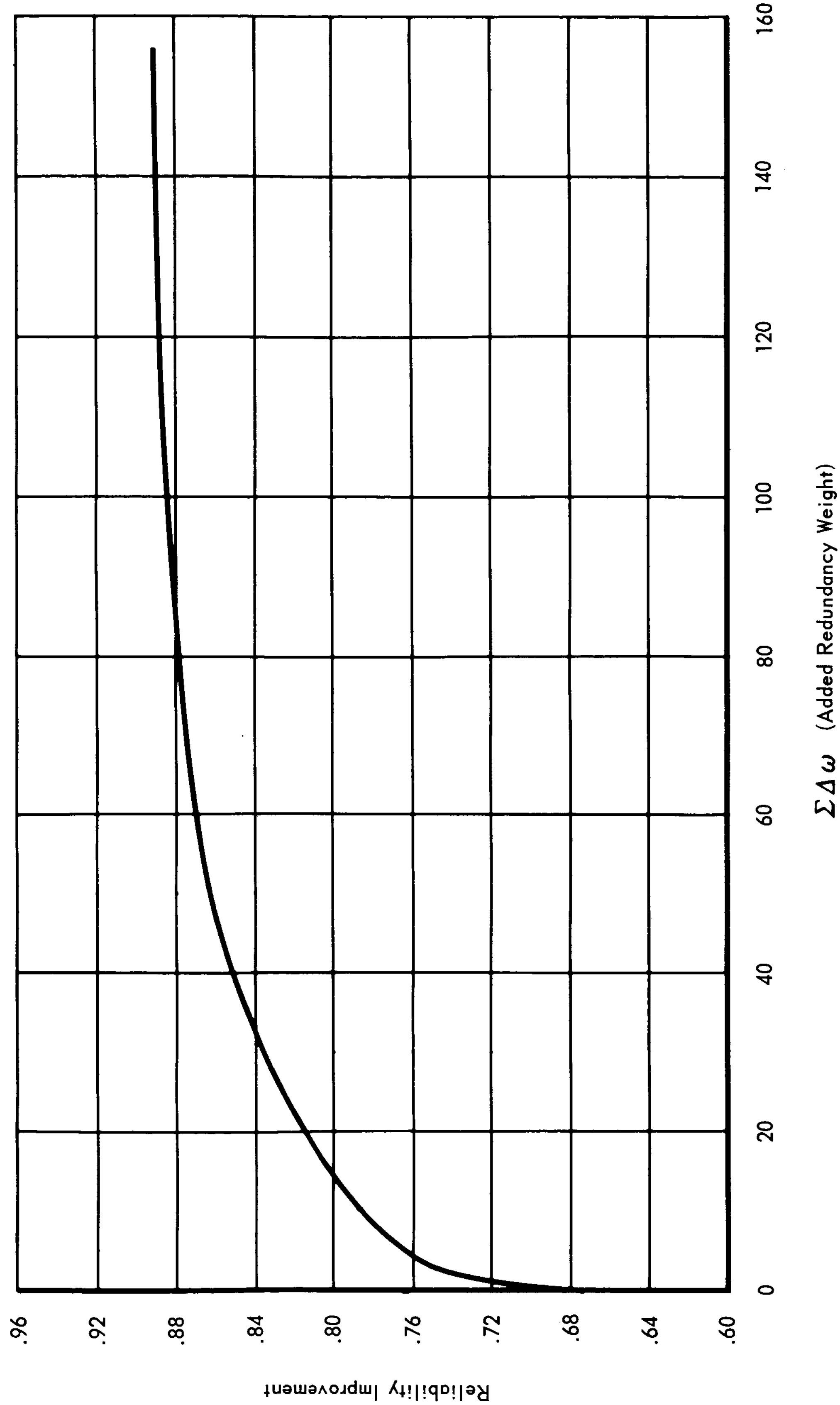


Figure 2.3.2-3

V_3 = Value index for the performance of Landed Science experiments

and, R_1 = Reliability index for the achievement of landing

R_2 = Reliability index for the performance of Entry Science experiments

R_3 = Reliability index for the performance of Landed Science experiments

Based on the competing characteristics criterion described in the "Specification for Performance and Design Requirements for the 1973 VOYAGER Mission", it was established that the value index should have the relationship $V_1 + V_2 + V_3 = 1$ and $V_1 > V_2 > V_3$. An effectiveness model was developed to work the problem and is described and shown in Part B Section 4.10 of Volume II.

As an example of the results of this analysis, Figure 2.3.3-1, shows a tabulation of the priority rating for redundancy considerations based on the assigment of value indices: $V_1 = .40$, $V_2 = .35$ and $V_3 = .25$. Comparisons of redundancy considerations from a reliability versus weight analysis and an effectiveness analysis are tabulated in Figure 2.3.3-2.

2.3.4 Summary of Selected Redundancies - Engineering judgment and the effectiveness analysis results were used as the criteria for selecting the preferred system-concept redundancies. The primary criterion, engineering judgment, required backup capability for the performance of all critical mission events. This capability was provided regardless of the efficiency of weight increase to reliability improvement. After providing this capability, the selection of additional equipment redundancies was guided by the effectiveness analysis. The eighty-two (82) redundancies selected for the preferred concept are tabulated in Figure 2.3.4-1. Sixty-three (63) are functional and consequently added minimal weight.

2.3.5 Redundancy Implementation Policy - The basic redundancy implementation policy was modified as a result of the effectiveness analysis. Prior to this analysis, equal emphasis was placed on the redundancy considerations for Capsule Bus, Entry Science Package and Surface Laboratory. As the design concepts evolved, it became apparent this policy of equal emphasis must be modified to most effectively utilize a prime resource -- weight. Therefore the effectiveness analysis technique was used as the redundancy implementation policy.

CAPSULE BUS REDUNDANCY CONSIDERATIONS
(EFFECTIVENESS ANALYSIS)

ORDER OF PRIORITY	REDUNDANCY CONSIDERATION	SUBSYSTEM	TYPE
1	Active redundant DC-DC Converter Regulator	Electrical Power	Multichannel
2	Standby redundant cruise encoder	Telecommunications	Block
3	Surface laboratory power provide back-up to capsule bus power	Electrical Power	Block
4	Series active redundant cruise commutator, data switches and switch drivers	Telecommunications	Multichannel
5	Standby redundant battery float chargers	Electrical Power	Block
6	Active redundant reefing cutters for each reefing line	Staging	Multichannel
7	Multiaxis gyro sensing	Guidance & Control	Block
8	Active redundant cruise commutator relays	Electrical Power	Multichannel
9	Active redundant command decoder relays	Electrical Power	Multichannel
10	Active redundant battery charger relays	Electrical Power	Multichannel
11	Series active redundant cruise monitor control, data switches, and switch drivers	Telecommunications	Multichannel
12	Redundant velocity channel in landing radar	Guidance & Control	Multichannel
13	Series active redundant adapter cruise commutator, data switches, switch drivers, and redundant cruise encoder	Telecommunications	Multichannel & Block
14	Standby redundant guidance and control computers	Guidance & Control	Block
15	Active redundant receivers and trackers in radar altimeter	Guidance & Control	Multichannel
16	Active redundant thermostats for heater control	Thermal Control	Multichannel
17	Interleave low rate data on ESP radio link	Telecommunications	Functional
18	Dual cartridge explosive bolts for capsule bus/ adapter separation	Staging	Multichannel
19	Standby redundant accelerometers and associated electronics	Guidance & Control	Block

Figure 2.3.3-1

20	Active redundant crystal controlled oscillators	Sequencer & Timer	Multichannel
21	Dual cartridge explosive bolts for deorbit motor release	Staging	Multichannel
22	Dual cartridge explosive bolts for aeroshell release	Staging	Multichannel
23	Redundant cartridge in each of three N.C. reaction control system pyro values	Propulsion	Multichannel
24	Redundant initiators in parachute catapult	Staging	Multichannel
25	Duplex memories and memory buffer registers with error detection	Sequence & Timer	Block
26	Triple redundant frequency dividers with majority voters	Sequence & Timer	Multichannel
27	Dual cartridge explosive bolts for parachute release	Staging	Multichannel
28	Series redundant pressure regulator in the in the reaction control system	Propulsion	Multichannel
29	Standby redundant transmitter tubes in the radar altimeter	Guidance & Control	Block
30	Active redundant resistance heaters	Thermal Control	Multichannel
31	Triple redundant decrementers and zero detectors with majority voters	Sequencer & Timer	Multichannel
32	Added element redundancy to the landing radar	Guidance & Control	Block
33	Active redundant discrete output line drivers	Sequencer & Timer	Multichannel
34	Triple redundant control logic with majority voters	Sequencer & Timer	Multichannel
35	Quad redundant input power diodes	Electrical Power	Multichannel
36	Dual cartridges explosive bolts for release of stabilizer legs	Landing	Multichannel
37	Active redundant telemetry, command link, reference frequency, and digital data interfaces	Sequencer & Timer	Multichannel
38	Active redundant sensor interfaces	Sequencer & Timer	Multichannel
39	Triple redundant discrete output gates with majority voters	Sequencer & Timer	Multichannel
40	Active redundant bias voltage and logic voltage regulators	Sequencer & Timer	Multichannel

CAPSULE BUS REDUNDANCY CONSIDERATIONS (Continued)

(EFFECTIVENESS ANALYSIS)

ORDER OF PRIORITY	REDUNDANCY CONSIDERATION	SUBSYSTEM	TYPE
41	Redundancy cartridge in each of three N.C. terminal propulsion system pyro valves	Propulsion	Multichannel
42	Redundant springs for deorbit motor separation	Staging	Multichannel
43	Series redundant pressure regulator in the terminal propulsion system	Propulsion	Multichannel
44	Active redundant battery power distribution relays	Electrical Power	Multichannel
45	Redundant cartridge in each of two N.O. terminal propulsion system pyro valves.	Propulsion	Multichannel
46	Active redundant subsystem control relays	Electrical Power	Multichannel
47	Redundant reaction control system pressurant supply	Propulsion	Multichannel
48	Active redundant guidance & control system power supplies	Guidance & Control	Multichannel
49	Quad redundant reaction control system thrust chamber propellent valves	Propulsion	Multichannel
50	Redundant shielded mild detonating cord assembly for canister release	Staging	Multichannel
51	Redundant check valves in the terminal propulsion system	Propulsion	Multichannel
52	Redundant compression spring for canister separation	Staging	Multichannel
53	Active redundant heater relays (post separation)	Electrical Power	Multichannel
54	Standby redundant CRS commutator and encoder	Telecommunications	Block
55	Active redundant heater relays (pre separation)	Electrical Power	Multichannel
56	Active redundant master test programmer relays	Electrical Power	Multichannel
57	Quad redundant 0.05g switches	Guidance & Control	Multichannel
58	Standby redundant programmer	Telecommunications	Block
59	Active redundant squib batteries	Electrical Power	Multichannel
60	Parallel redundant engine valves in the terminal propulsion system	Propulsion	Multichannel
61	Active redundant main battery	Electrical Power	Multichannel
62	Active redundant (load sharing) telemetry power supply	Telecommunications	Multichannel
63	Quad redundant battery power diodes	Electrical power	Multichannel
64	Quad redundant squib battery diodes	Electrical Power	Multichannel

Figure 2.3.3-1 (Continued)

RELIABILITY vs. WEIGHT AND EFFECTIVENESS ANALYSIS
REDUNDANCY PRIORITY COMPARISON

RELIABILITY vs. WEIGHT	EFFECTIVENESS ANALYSIS	REDUNDANCY CONSIDERATION	SUBSYSTEM	TYPE
1	2	Standby Redundant Cruise Encoder	Telecommunications	Block
2	4	Series Activity Redundant Cruise Commutator, Data Switches and Switch Drivers	Telecommunications	Multi-channel
3	17	Interleaver Low Rate Data on ESP Radio Link	Telecommunications	Functional
4	11	Series Active Redundant Cruise Monitor Control, Data Switches and Switch Drivers	Telecommunications	Multi-channel
5	13	Series Active Redundant Adapter Cruise Commutator, Data Switches, Switch Drivers and Redundant Cruise Encoder	Telecommunications	Multi-channel & Block
6	3	Surface Laboratory Power Provide Backup to Capsule Bus Power	Electrical Power	Block
7	1	Active Redundant DC–DC Converter Regulator	Electrical Power	Multi-channel
8	5	Standby Redundant Battery Float Chargers	Electrical Power	Block
9	6	Active Redundant Reefing Cutters for Each Reefing Line	Staging	Multi-channel
10	54	Standby Redundant CBS Commutator and Encoder	Telecommunications	Block
11	7	Multi-axis Gyro Sensing	Guidance & Control	Block
12	8	Active Redundant Cruise Commutator Relays	Electrical Power	Multi-channel
13	9	Active Redundant Command Decoder Relays	Electrical Power	Multi-channel
14	10	Active Redundant Battery Charger Relays	Electrical Power	Multi-channel
15	58	Standby Redundant Programmer	Telecommunications	Block
16	12	Redundant Velocity Channel in Landing Radar	Guidance & Control	Multi-channel
17	14	Standby Redundant Guidance and Control Computers	Guidance & Control	Block
18	15	Active Redundant Receivers and Trackers in Radar Altimeter	Guidance & Control	Multi-channel
19	16	Active Redundant Thermostats for Heater	Thermal Control	Multi-channel

Figure 2.3.3–2

		Control		
20	18	Dual Cartridge Explosive Bolts for Capsule Bus/Adapter Separation	Staging	Multi-channel
21	19	Standby Redundant Accelerometers and Associated Electronics	Guidance & Control	Block
22	20	Active Redundant Crystal Controlled Oscillators	Sequencer & Timer	Multi-channel
23	21	Dual Cartridge Explosive Bolts for De-orbit Motor Release	Staging	Multi-channel
24	22	Dual Cartridge Explosive Bolts for Aeroshell Release	Staging	Multi-channel
25	23	Redundant Cartridge in Each of Three NC Reaction Control System Pyro Valves Redundant Initiators in Parachute Catapult	Propulsion	Multi-channel
26	24	Redundant Initiators in Parachute Catapult	Staging	Multi-channel
27	25	Duplex Memories and Memory Buffer Registers With Error Detection Switching Logic	Sequencer & Timer	Block
28	26	Triple Redundant Frequency Dividers With Majority Voters	Sequencer & Timer	Multi-channel
29	27	Dual Cartridge Explosive Bolts for Parachute Release	Staging	Multi-channel
30	62	Active Redundant (Load Sharing) Telemetry Power Supply	Telecommunications	Multi-channel
31	28	Series Redundant Pressure Regulator in the Reaction Control System	Propulsion	Multi-channel
32	29	Standby Redundant Transmitter Tubes in the Radar Altimeter	Guidance & Control	Block

RELIABILITY vs. WEIGHT AND EFFECTIVENESS ANALYSIS (Continued)

RELIABILITY vs. WEIGHT	EFFECTIVENESS ANALYSIS	REDUNDANCY CONSIDERATION	SUBSYSTEM	TYPE
33	30	Active Redundant Resistance Heaters	Thermal Control	Multi-channel
34	36	Dual Cartridges Explosive Bolts for Release of Stabilizer Legs	Landing	Multi-channel
35	31	Triple Redundant Decrementers and Zero Detectors With Majority Voters	Sequencer & Timer	Multi-channel
36	32	Added Element Redundancy to the Landing Radar	Guidance & Control	Block
37	33	Active Redundant Discrete Output Line Drivers	Sequencer & Timer	Multi-channel
38	41	Redundant Cartridge in Each of Three NC Terminal Propulsion System Pyro Valves	Propulsion	Multi-channel
39	34	Triple Redundant Control Logic With Majority Voters	Sequencer & Timer	Multi-channel
40	35	Quad Redundant Input Power Diodes	Electrical Power	Multi-channel
41	38	Active Redundant Sensor Interfaces	Sequencer & Timer	Multi-channel
42	37	Active Redundant Telemetry, Command Link, Reference Frequency and Digital Data Interfaces	Sequencer & Timer	Multi-channel
43	43	Series Redundant Pressure Regulator in the Terminal Propulsion System	Propulsion	Multi-channel
44	39	Triple Redundant Discrete Output Gates With Majority Voters	Sequencer & Timer	Multi-channel
45	40	Active Redundant Bias Voltage and Logic Voltage Regulators	Sequencer & Timer	Multi-channel
46	45	Redundant Cartridge in Each of Two NO	Propulsion	Multi-channel

Figure

2-19-1

4[illegible]	4[illegible]	Terminal Propulsion System Pyro Valves		
47	42	Redundant Springs for De-orbit Motor Separation	Staging	Multi-channel
48	44	Active Redundant Battery Power Distribution Relays	Electrical Power	Multi-channel
49	46	Active Redundant Subsystem Control Relays	Electrical Power	Multi-channel
50	47	Redundant Reaction Control System Pressurant Supply	Propulsion	Multi-channel
51	48	Active Redundant Guidance and Control System Power Supplies	Guidance & Control	Multi-channel
52	51	Redundant Check Valves in the Terminal Propulsion System	Propulsion	Multi-channel
53	49	Quad Redundant Reaction Control System Thrust Chamber Propellant Valves	Propulsion	Multi-channel
54	50	Redundant Shielded Mild Detonating Cord Assembly for Canister Release	Staging	Multi-channel
55	52	Redundant Compression Spring for Canister Separation	Staging	Multi-channel
56	53	Active Redundant Heater Relays (Post Separation)	Electrical Power	Multi-channel
57	55	Active Redundant Heater Relays (Pre Separation)	Electrical Power	Multi-channel
58	56	Active Redundant Master Test Programmer Relays	Electrical Power	Multi-channel
59	57	Quad Redundant 0.05g Switches	Guidance & Control	Multi-channel
60	60	Parallel Redundant Engine Valves in the Terminal Propulsion System	Propulsion	Multi-channel
61	59	Active Redundant Squib Batteries	Electrical Power	Multi-channel
62	61	Active Redundant Main Bettery	Electrical Power	Multi-channel
63	63	Quad Redundant Battery Power Diodes	Electrical Power	Multi-channel
64	64	Quad Redundant Squib Battery Diodes	Electrical Power	Multi-channel

2.3.3–2 (Continued)

CAPSULE BUS SELECTED REDUNDANCIES

TYPE	EVENT	PRIMARY SOURCE	REDUNDANT SOURCE
Functional	Switch flight capsule to flight spacecraft power	Flight spacecraft central computer & sequencer	Mission operations system
	Switch flight capsule to battery power	Flight spacecraft central computer & sequencer	Mission operations system
	Turn on capsule bus test programmer	Flight spacecraft central computer & sequencer	Mission operations system
	Turn on capsule bus telemetry subsystem	Capsule bus test programmer	Mission operations system
	Turn on guidance and control inertial measuring unit	Capsule Bus sequencer and timer	Mission operations system
	Switch capsule bus telemetry subsystem to checkout mode	Capsule bus test programmer	Mission operations system
	Switch entry science package, surface laboratory and capsule bus cruise commutators to capsule bus telemetry control mode	Capsule bus test programmer	Mission operations system
	Turn on entry science package telemetry subsystem	Capsule bus test programmer	Mission operations system
	Switch entry science package telemetry subsystem to checkout mode	Capsule bus test programmer	Mission operations system
	Turn off entry science package telemetry subsystem	Capsule test programmer	Mission operations system
	Switch entry science package, capsule bus and surface laboratory cruise commutators to cruise mode	Capsule bus test programmer	Mission operations system
	Turn off capsule bus telemetry subsystem	Capsule bus test programmer	Mission operations system
	Turn on surface lab telemetry subsystem	Capsule bus test programmer	Mission operations system
	Turn on surface lab test programmer	Capsule bus test programmer	Mission operations system
	Turn off surface lab test programmer	Capsule bus test programmer	Mission operations system
	Apply power to capsule bus sequencer and timer	Flight spacecraft central computer & sequencer	Mission operations system
	Switch capsule bus, entry science package and surface lab to internal power	Capsule bus sequencer and timer	Flight spacecraft central computer and sequencer or Mission operations system
	Turn on capsule bus guidance and control subsystem computer	Capsule bus sequencer and timer	Mission operations system

Figure 2.3.4-1

CAPSULE BUS SELECTED REDUNDANCIES (Continued)

TYPE	EVENT	PRIMARY SOURCE	REDUNDANT SOURCE
Functional	Transfer guidance and control subsystem data words to guidance and control computer	Capsule bus sequencer and timer	Mission operations system
	Activate capsule bus squib battery No. 1	Capsule bus sequencer and timer	Mission operations system
	Activate capsule bus squib battery No. 2	Capsule bus sequencer and timer	Mission operations system
	Activate capsule bus squib battery No. 3	Capsule bus sequencer and timer	Mission operations system
	Turn-on Low-Rate UHF transmitter	Capsule bus sequencer and timer	Mission operations system
	Switch capsule bus telemetry subsystem to deorbit mode	Capsule bus sequencer and timer	Mission operations system
	Swtich capsule bus, surface lab and entry science package cruise commutators to capsule bus control mode	Capsule bus sequencer and timer	Mission operations system
	Switch sterilization canister to internal power	Capsule bus sequencer and timer	Mission operations system
	Release and separate forward section of canister	Canister dual programmer	Capsule bus sequencer and timer
	Separate insulation from flight capsule	Canister dual programmer	Capsule bus sequencer and timer
	Release flight capsule from flight spacecraft (electrical)	Canister dual programmer	Capsule bus sequencer and timer
	Release flight capsule from flight spacecraft (mechanical)	Canister dual programmer	Capsule bus sequencer and timer
	Terminate deorbit motor thrust	Capsule bus guidance and control computer	Capsule bus sequencer and timer
	Separate spent deorbit motor	Capsule bus pyro delay	Capsule bus sequencer and timer
	Turn on capsule bus radar altimeter	Capsule bus sequencer and timer	.05 g sensor
	Initiate capsule bus guidance a and control computer routine	Capsule bus sequencer and timer	Capsule bus radar altimeter
	Turn on entry science package telemetry subsystem, base pressure experiment, descent TV (warmup), accelerometer experiment, stagnation pressure experiment, radio subsystem, data storage subsystem and switch entry science package telemetry subsystem to entry mode	Capsule bus sequencer and timer	.05 g sensor or capsule bus radar altimeter

Figure 2.3.4-1 (Continued)

CAPSULE BUS SELECTED REDUNDANCIES (Continued)

TYPE	EVENT	PRIMARY SOURCE	REDUNDANT SOURCE
Functional	Switch capsule bus telemetry system to entry mode	Capsule bus sequencer and timer	.05 g sensor or, capsule bus radar altimeter
	Initiate descent TV camera sequencing	Capsule bus sequencer and timer	.05 g sensor or capsule bus radar altimeter
	Initiate capsule bus integrating acceleration sensing route	Capsule bus sequencer and timer	Capsule bus radar altimeter
	Arm terminal propulsion system pressurant and isolation valves	Capsule bus sequencer and timer	Capsule bus radar altimeter
	Fire terminal propulsion system pressurant isolation valves	Capsule bus sequencer and timer	Capsule bus radar altimeter
	Fire terminal propulsion system propellant isolation valves	Capsule bus sequencer and timer	Capsule bus radar altimeter
	Switch to 3-axis rate damping and initiate guidance and control computer inertial reference routine	Capsule bus guidance and control subsystem	Capsule bus radar altimeter
	Turn on capsule bus landing radar	Capsule bus radar altimeter	.05 g sensor or capsule bus integrated acceleration sensing routine
	Update capsule bus sequencer and timer based on altitude or integrated acceleration sensing	Capsule bus radar altimeter	Capsule bus integrated acceleration sensing routine
	Enable capsule bus aerodecelerator deployment mechanism	Capsule bus sequencer and timer	Capsule bus radar altimeter
	Deploy capsule bus aerodecelerator	Capsule bus sequencer and timer	Capsule bus radar altimeter
	Arm capsule bus aeroshell separation mechanism and initiate guidance and control computer descent control mode	Capsule bus sequencer and timer	Capsule bus radar altimeter
	Release capsule bus aeroshell from capsule bus (electrical)	Capsule bus sequencer and timer	Capsule bus radar altimeter
	Release capsule bus aeroshell from capsule bus (mechanical)	Capsule bus sequencer and timer	Capsule bus radar altimeter
	Separate capsule bus aeroshell from capsule bus and switch entry science package telemetry subsystem and capsule bus telemetry subsystem to terminal descent mode	Capsule bus sequencer and timer	Capsule bus radar altimeter

Figure 2.3.4–1 (Continued)

CAPSULE BUS SELECTED REDUNDANCIES (Continued)

TYPE	EVENT	PRIMARY SOURCE	REDUNDANT SOURCE
Functional	Ignite terminal propulsion motors	Capsule bus radar altimeter	Capsule bus landing radar
	Release capsule bus aerodecelerators	Capsule bus sensor	Capsule bus radar altimeter or sequencer and timer
	Throttle down terminal propulsion motors to .8 g	Capsule bus guidance and control computer	Capsule bus sequencer and timer
	Switch landing radar range scale	Capsule bus landing radar	Capsule bus radar altimeter
	Begin constant velocity descent	Capsule bus guidance and control subsystem	Capsule bus radar altimeter
	Enable capsule bus and surface lab impact sensors and release descent TV cameras	Capsule bus radar altimeter	Capsule bus landing radar
	Terminate capsule bus terminal propulsion motor burn and capsule bus attitude control electronics	Capsule bus landing radar	Capsule bus sequencer and timer or impact sensor or surface lab impact sensor
	Update capsule bus sequencer and time base on time of impact	Capsule bus impact sensor	Surface lab sequencer and timer
	Terminate capsule bus landing radar and radar altimeter operation	Capsule bus impact sensor	Capsule bus sequencer and timer or surface lab impact sensor
	Arm capsule bus stabilizer legs	Capsule bus sequencer and timer	Surface lab sequencer and timer
	Release capsule bus stabilizer legs	Capsule bus sequencer and timer	Surface lab sequencer and timer
	Extend capsule bus stabilizer legs	Capsule bus sequencer and timer	Surface lab sequencer and timer
	Shut down entry science package	Capsule bus sequencer and timer	Surface lab sequencer and timer
	Switch capsule bus to surface lab support mode	Capsule bus sequencer and timer	Surface lab sequencer and timer

Figure 2.3.4-1 (Continued)

SECTION 3

QUANTITATIVE RELIABILITY ESTIMATES

The primary purpose of the reliability estimates is to show relative comparisons of reliability potentials of the many concepts considered, rather than to accurately predict the reliability of a given concept or the preferred concept.

3.1 RELIABILITY ESTIMATE METHODS - The methods used in performing reliability estimates for the studies were maintained consistent with the level of design maturity. The primary elements necessary for establishing a quantitative reliability estimate are discussed in the following paragraphs.

3.1.1 Mission Profile Analysis - The mission profile presented in the VOYAGER Specification was examined in detail and a representative mission for the Capsule Bus was established for reliability estimates. Mission events were examined to determine the possible effect of the events on subsystem reliability. This examination resulted in the establishment of failure rate modifiers to be applied in determining an equivalent mission duty cycle. The mission events and applicable failure rate modifying factors are listed in Figure 3.1.1-1. Modifying factors are shown for both operating and non-operating equipment. The factors depict the significant relative environmental and application stresses for the different events.

3.1.2 Subsystem Configuration Definition - A necessary step in the computation of a reliability estimate is to determine the function and operations of the subsystem and its major components or assemblies. This was accomplished by a study of the subsystem functional block diagram. A typical subsystem functional block diagram is illustrated by Figure 3.1.2-1.

From this information a reliability logic diagram was prepared for the subsystem. This is a "success path" diagram showing those components and/or subassemblies which must function in order for the subsystem to successfully complete its mission. The reliability diagram expands in detail as the design matures. A typical reliability block diagram is illustrated by Figure 3.1.2-2.

3.1.3 Failure Rate Determination - With a subsystem reliability diagram defined, the next step in performing a reliability estimate was to determine a failure rate for each item or block in the reliability diagram. For the less complex subassemblies and/or components which appear in the diagram, the historical failure rate of a similar item was used. The parts count technique as illustrated by Figure 3.1.3-1 was used for all other assemblies and/or components. Average failure rates were

VOYAGER MARS MISSION PROFILE AND FAILURE RATE MODIFYING FACTORS FOR RELIABILITY ANALYSIS

MISSION EVENT	TIME (HRS)	MODIFYING FACTOR		MODIFIED TIME – t_m	
		OPERATING EQUIPMENT	NON-OPERATING EQUIPMENT	OPERATING EQUIPMENT	NON-OPERATING EQUIPMENT
Launch	0.20	150	150	30	30
Parking Orbit	0.54	1	.01	.54	.0054
Interplanetary Injection (Powered Flight)	0.09	3	3	.27	.27
Interplanetary Cruise (222 days + 4 days)	5424	1	0.01	5424	54.24
Trajectory Corrections (Powered Flight)	0.10*	3	3	.30	.30
Orbit Insertion (Powered Flight)	0.10*	3	3	.30	.30
Orbit Cruise (7.5 Orbits)	105	1	.01	105	1.05
De-orbit Maneuver (Powered Flight)	0.02	3	3	.06	.06
Orbit Descent	5	1	.01	5	.05
Entry	.10	6	6	.60	.60
Terminal Descent Aero	0.02	3	3	.06	.06
Terminal Descent Prop	0.02	6	6	.12	.12
Impact	.01	3,000	3,000	30	30
Landing Erection	.02	3	3	.06	.06
Landing Operation					
Exterior	$\leq$ 50	5	.01	$\leq$ 250	$\leq$ .50
Interior	$\leq$ 50	1	.01	$\leq$ 50	$\leq$ .50

* Estimate

Figure 3.1.1–1

CB SEQUENCER AND TIMER SCHEMATIC BLOCK DIAGRAM

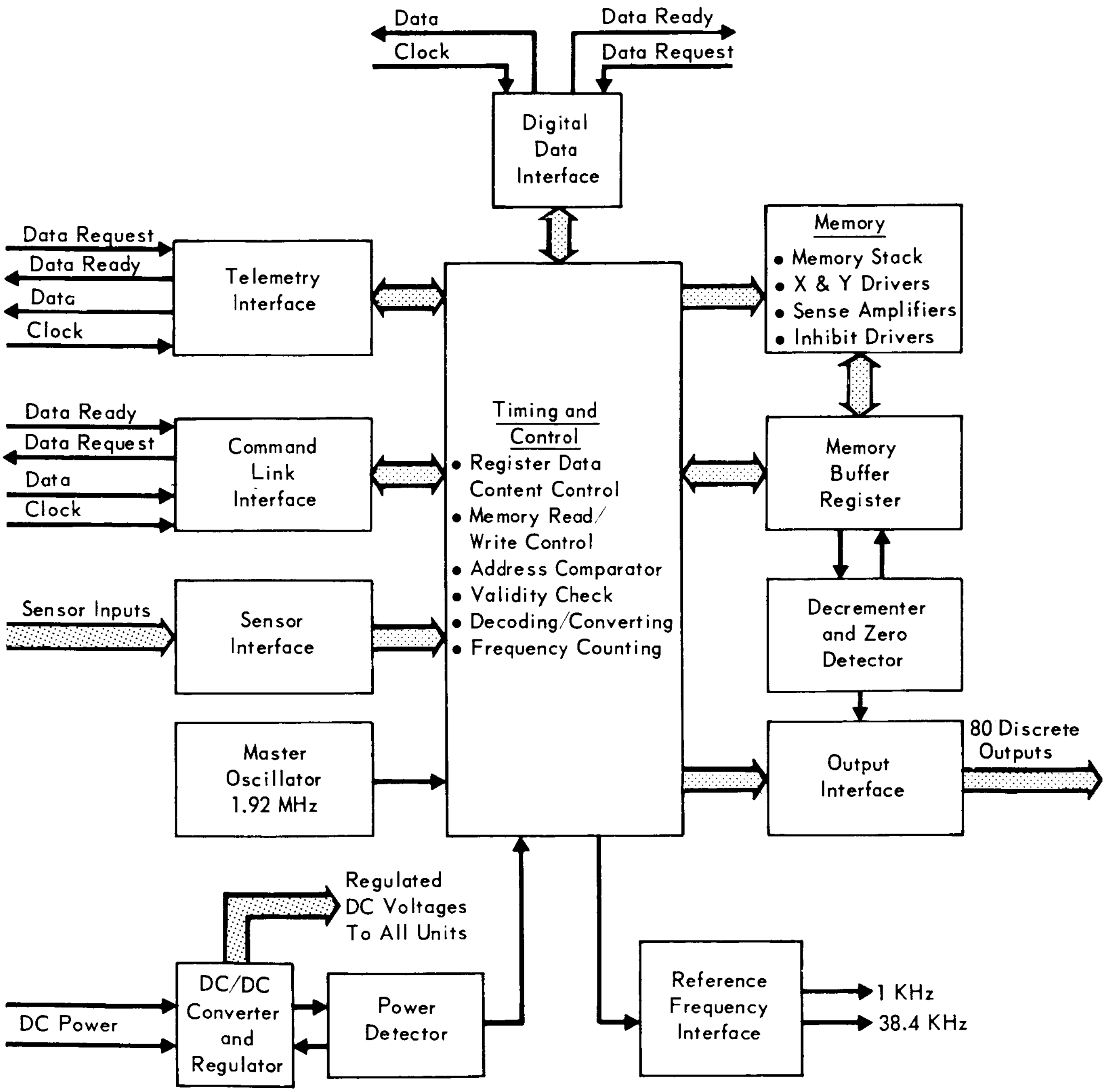


Figure 3.1.2-1

CAPSULE BUS SEQUENCER & TIMER RELIABILITY MODEL

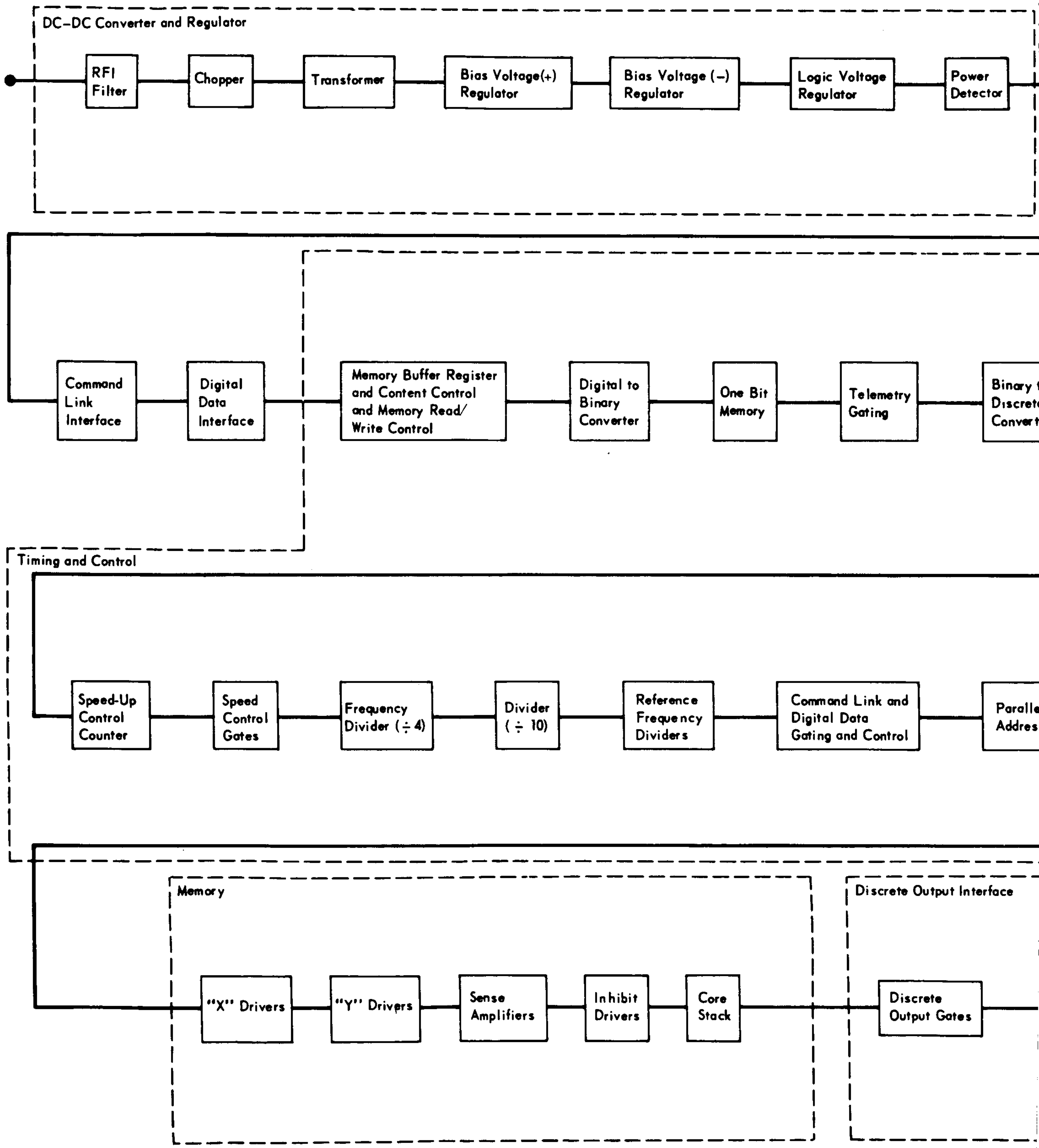
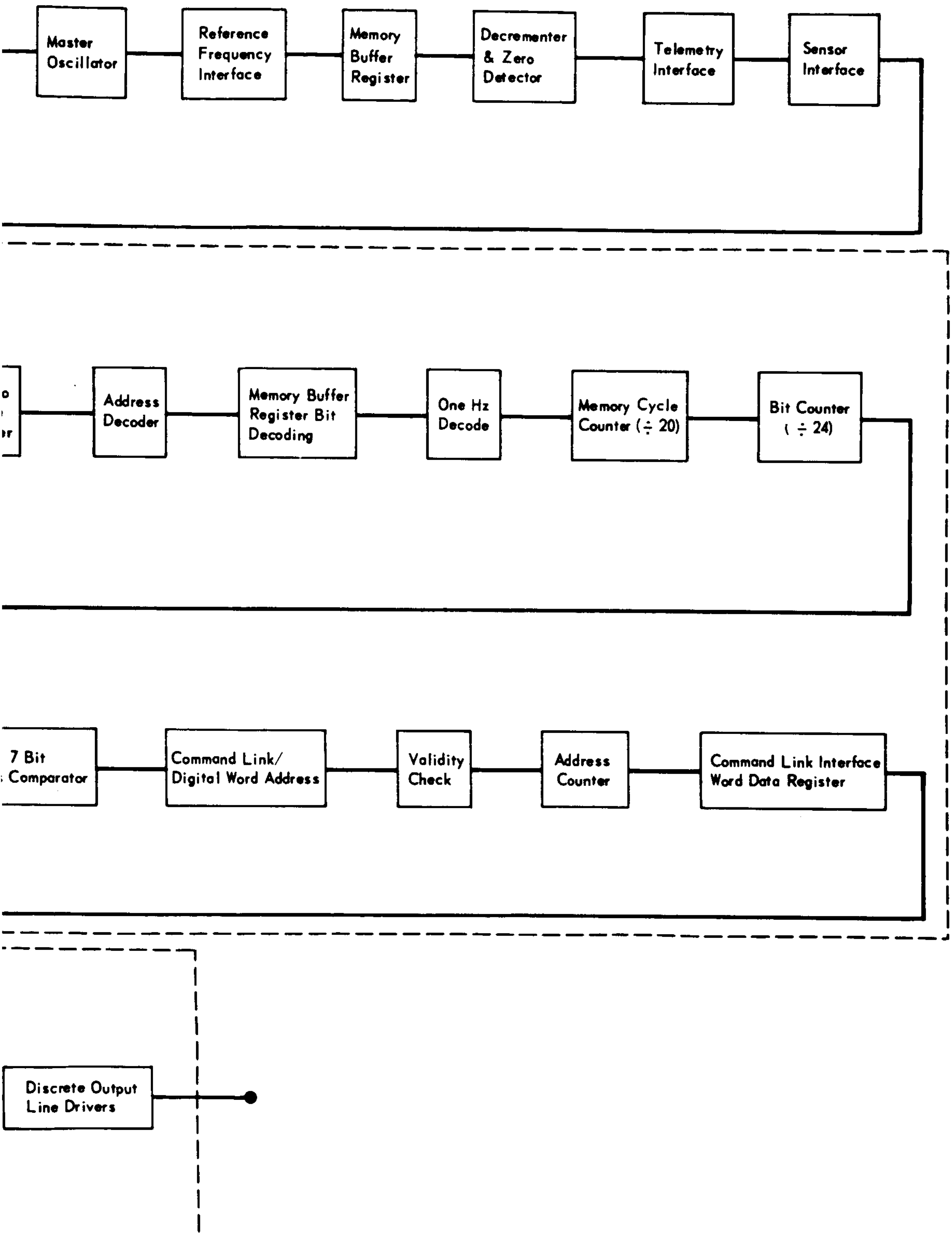


Figure 3.1.2–2


Master Oscillator
Reference Frequency Interface
Memory Buffer Register
Decrementer & Zero Detector
Telemetry Interface
Sensor Interface
Address Decoder
Memory Buffer Register Bit Decoding
One Hz Decode
Memory Cycle Counter (÷ 20)
Bit Counter (÷ 24)
7 Bit Comparator
Command Link/ Digital Word Address
Validity Check
Address Counter
Command Link Interface Word Data Register
Discrete Output Line Drivers

PARTS COUNT ESTIMATE
CAPSULE BUS SEQUENCER AND TIMER MEMORY SUBASSEMBLY

COMPONENT	QUANTITY (n)	FAILURE RATE $\lambda \times 10^6$/hr	$n\lambda \times 10^6$
"X" Drivers			
Integrated Circuits	4	.10	.400
Transistors, Silicon	32	.05	1.600
Resistors, Carbon	64	.001	.064
"Y" Drivers			
Integrated Circuits	2	.10	.200
Transistors, Silicon	16	.05	.800
Resistors, Carbon	32	.001	.032
Sense Amplifiers			
Integrated Circuits	24	.10	2.400
Inhibit Drivers			
Transistors, Silicon	48	.05	2.400
Resistors, Carbon	96	.001	.096
Core Stack			
Cores	3072	.003	9.216
Subassembly Failure Rate = $\Sigma\, n\lambda$ = 17.208×10^{-6}			

Figure 3.1.3-1

used for all other assemblies and/or components. Average failure rates were used for the different component parts with no attempt to predict part derating or environmental stresses internal to the assembly. To insure good relative comparisons of the estimated reliability of competing concepts, a list of standard failure rates for electrical and electronic piece parts was established and used for all parts count estimates. This same technique can be extended to include the effects of part derating and operating environments as the detailed design of the assemblies materializes. The part count technique provides an effective tool for determining areas in which reliability can be improved by effective part derating or by incorporating redundancy within the assembly.

3.1.4 <u>Subsystem Reliability Estimate</u> - The final step in arriving at a subsystem or concept quantitative reliability estimate was to combine the above elements. Figure 3.1.4-1 illustrates one technique for arriving at the subsystem estimate. A modified time (t_m) was determined for each subassembly by applying the modifying factors as previously shown in Figure 3.1.1-1 to the mission duty cycle of the subassembly. This time (t_m), for time dependent items, was then multiplied by the failure rate of the item to find the mission failure rate for each item. The summation of these mission failure rates gives the subsystem mission failure rate. The subsystem mission reliability was determined by use of the formula

$$R = e^{-\lambda t_m}$$

3.2 RELIABILITY ESTIMATE LIMITATIONS - The limitations of quantitative reliability estimates must be recognized if results are to be interpreted properly. Quantitative estimates for system and subsystem reliability made during this concept definition phase have accuracy limited by the level of design maturity. Quantitative reliability estimates are a valuable input to early design decisions and will become more and more significant as the design becomes more detailed. The emphasis will gradually shift from comparative estimates toward predictive estimates as the design evolves, with the failure mode, effect and criticality analyses being of primary importance in design shaping.

3.3 SUMMARY OF RELIABILITY ESTIMATE RESULTS - The primary use of the quantitative reliability estimates has been for comparative evaluation of competing subsystem concepts rather than to predict the actual reliability of a given concept or the preferred concept. A quantitative reliability estimate was a standard input to major design trade studies and was a major factor in many decisions. The estimates have served to highlight areas for reliability improvement. The reliability estimates were a necessary input to the reliability versus weight and effectiveness analysis.

RELIABILITY ESTIMATE
CAPSULE BUS SEQUENCER AND TIMER

COMPONENT OR SUBASSEMBLY	t_m(HR)	FAILURE RATE $\lambda \times 10^6$/HR	$\lambda t_m \times 10^6$ ($-\ln R \times 10^6$)
DC-DC Converter and Regulators	126	3.127	394
Memory	126	17.208	2168
Crystal Oscillator	126	.833	105
Memory Buffer Register	126	3.00	378
Sensor Interface	126	.416	52
Decrementer and Zero Detector	126	.500	63
Telemetry Interface	126	.104	13
Command Link Interface	126	.104	13
Digital Data Interface	126	.104	13
Reference Frequency Interface	126	.104	13
Timing and Control	126	18.200	2293
Power Detector	126	.043	5
Output Interface	126	10.160	1280
			$\Sigma = 6792$
			$R = e^{-\Sigma \lambda t_m} = .9932$

Figure 3.1.4–1

A quantitative reliability estimate of the selected Capsule Bus configuration has been computed and is presented in Figure 3.3-1. This estimate indicates that the propulsion, telecommunications, electrical power, and guidance and control subsystems will collectively have the greatest influence on Capsule Bus reliability.

VOYAGER CAPSULE BUS EQUIPMENT RELIABILITY ESTIMATE SUMMARY

SUBSYSTEM	MISSION RELIABILITY ESTIMATE
Guidance and Control	.938
Inertial Measuring Unit	
Guidance and Control Computer	
Radar Altimeter	
Landing Radar	
Telecommunication	.952
Telemetry	
Radio	
Antenna	
Command	
Data Storage	
Instrumentation	
Electrical Power	.984
Converter-Regulator	
Power Switching and Logic	
Battery Charger	
Main Battery	
Squib-Motor Batteries	
Propulsion	.962
Deorbit Propulsion	
Reaction Control	
Terminal Propulsion	
Landing	.998
Impact Attenuation	
Stabilization	
Sequencer and Timer	.993
Staging	.994
Aerodynamic Decelerator	
Separation and Release Functions	
Thermal Control	.997
Total Capsule Bus Equipment Reliability	.830

Figure 3.3–1

SECTION 4

RELIABILITY PROGRAM REQUIREMENTS

The Phase B study has revealed several reliability program elements which must receive increased major emphasis throughout the program. These elements are: (1) Failure modes, effects, and criticality analysis, (2) Specially planned parts and materials program, (3) Positive failure analysis, evaluation and corrective action, and (4) Comprehensive design reviews.

4.1 FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS - FMECA is a powerful reliability technique for highlighting potential design weakness. It must be a primary continuing reliability task performed concurrently with the detail design and previously described contingency analysis. The FMECA carried to the detail level provides the basis for design considerations which minimize mission failures or degradation.

4.2 PARTS AND MATERIALS PROGRAM - The decontamination, sterilization, and long-life requirements demands the need for a specially planned comprehensive parts and materials program. This program must provide for the selection, testing, and control of parts and materials to assure that the parts and materials meet these environmental and life requirements and do not compromise equipment reliability.

4.3 FAILURE EVALUATION - "Failures" or performance irregularities must be expediently and positively identified, analyzed, and corrective action taken. This assures that no problem remains unidentified and immune to maximum corrective effort.

4.4 DESIGN REVIEWS - In depth design reviews must be conducted on all elements of the Capsule Bus System. The design review process must also place equal emphasis on the review of the operational support equipment compatibility with the system and/or subsystems. The compatibility must be clearly evaluated by design review to assure that the interface design of the operational support equipment and flight equipment will not compromise the launch constraints.

SECTION 5

COMPONENT PART RELIABILITY

Recognizing that system reliability is influenced by the characteristics and application of the component parts, we have devoted our Phase B effort to: (1) determining the elements of a realistic component part plan , and (2) initiating certain elements of this plan.

The elements of the plan are:

a. An Approved Parts List (APL) listing those parts demonstrating ability to meet VOYAGER Capsule Bus requirements.

b. Specification control for all parts.

c. Parts Application Manual for electrical and mechanical parts.

d. Parts Test Program.

e. Traceability program.

During Phase B we have begun work on elements a, b, c, and d as reported in the paragraphs immediately following.

5.1 APPROVED PARTS AND MATERIALS LIST - During Phase B, a preliminary Approved Parts List (APL) was issued and used by the design functions as a guide where part information was required to conduct meaningful implementation studies. The data used to generate the list were taken from JPL Document ZPP-2010-SPL-C, "Electronic Parts Sterilization Candidates for Spacecraft Application." In addition an Approved Materials and Processes List was prepared based on data available to us from many sources and from in-house testing. Only those parts, materials and processes which exhibited evidence of meeting the VOYAGER Flight Capsule requirements were included in these lists. These two lists are McDonnell Douglas Reports F189 and E936, respectively.

The APL includes tabulations of specific electrical and mechanical parameters to aid the design groups in proper part selections for particular applications. The APL subdivides the parts into three categories.

a. <u>High Reliability</u> - These parts are VOYAGER preferred parts which have been subjected to long term failure rate life tests and have established low failure rates.

b. <u>Preferred Parts</u> - These parts are tested and qualified for use in the VOYAGER Flight Capsule environment.

c. Nonstandard - These parts are Special or Limited application, and receive specific testing and justification for use.

It is recognized that modification to the Approved Parts, Materials and Processes Lists will be required as the VOYAGER Program progresses. The continuing component part reliability program plan for the Phase C and D effort is detailed in Part C, Section 10 of Volume VI.

5.2 SPECIFICATION - Several special specifications were produced for the VOYAGER Flight Capsule Program during the Phase B study in preparation for the Phase C design effort. These specifications delineate the part requirements and the approved sources of supply. Approved sources of supply candidates were selected from JPL Document ZZP-2010-SPL-C.

To minimize duplication, a two level specification system is used as described below:

a. General Specification - A specification covering the general requirements for generic types or families of parts.

b. Detail Part Drawings - A specification delineating the detail requirements for a specific part.

Examples of existing specifications are as follows:

a. General Specification, VOYAGER Flight Capsule, Semiconductors, Transistors, Diodes and Integrated Circuits (207-780003)

b. Detail Part Drawing, Integrated Circuit, Flip-Flop, RST (207-780007)

c. Detail Part Drawing, Semiconductor, Diode, General Purpose, Power, Silicon (207-780004)

d. General Specification, VOYAGER Flight Capsule, Capacitors, Fixed (207-780005)

e. Detail Part Drawing, Capacitor, Fixed, Ceramic (207-780009)

The Semiconductor General Specification and the Integrated Circuit Detail Part Drawing are included in Appendix (A) as examples.

The procedure established for the issuance of additional specifications is given in the component part, material and processes program plan, Part C, Section 10 of Volume VI.

5.3 APPLICATION MANUAL - Part parameter control alone is not sufficient to assure satisfactory operation of the part. Our approach for the VOYAGER Flight Capsule System places equal emphasis on use of the best part and best use of the part. In conjunction with the Approved Parts List, a Parts Application Manual was initiated in Phase B as a guide for the design groups, and is discussed in more detail in Part C, Section 10 of Volume VI. The following information as a minimum is included in the manual:

a. Function of the part
b. Application considerations and limitations
c. Electrical characteristics
d. Environmental limitations
e. Failure modes
f. Failure rates
g. Physical properties
h. Packaging, mounting and handling limitations

5.3.1 Electrical Considerations - In order to assure high reliability designs, conservative derating of electrical stress for component parts is necessary. These derating factors were established and included in the initial issue of our applications manual. The following are examples of derating factors used:

a. Integrated Circuits - Fan-in and fan-out shall be such that the power dissipation shall not exceed 50 percent of maximum rating.
b. Power Transistors - Power dissipation shall not exceed 30 percent of rated maximum, base and emitter currents shall not exceed 75 percent of rated maximum, and voltages shall not exceed 75 percent of rated maximum.
c. Wire Wound Resistors (1 percent tolerance and up) - Power dissipation shall not exceed 50 percent of rated maximum.

These derating values are generic, and further evaluation is required for each individual part within the general part category.

5.3.2 Mechanical Considerations - Consistent with the level of detail design existing in the Phase B study, a review of the packaging, mounting, and environmental factors affecting parts was performed and comparisons made with the part limitations. The following items were considered in the review:

a. Thermal inertia
b. Thermal conductivity
c. Thermal radiation on adjacent parts
d. Vibration
e. Encapsulation
f. Mounting
g. Interconnection

This type of review must continue in depth as the design proceeds into Phase C and D.

The results of the review and results of mechanical and process tests provided the data for proper parts applications, and was reflected in the Approved Materials and Processes List and in the Parts Application Manual.

5.4 TESTING - Tests were conducted prior to and during Phase B to evaluate the effects of heat sterilization and decontamination cycles and shock. These tests, involving thirteen part types, resulted in very few failures.

a. Power diodes failed due to dessicant liberating moisture during the heat cycle. Although a large percentage of one diode type group exhibited high reverse current leakage, none of the failures resulted directly from the sterilization or shock environment.

b. Powdered iron core inductors failed when subjected to shock beyond that expected in the Flight Capsule.

For a summary discussion of the above part testing see Part B, Section 1.1 of Volume VI.

Several insulation and encapsulation materials are presently being evaluated in our laboratories sterilization temperature, operating temperature and at a pressure of 10^{-10} Torr to assure that outgassing and sublimation will not create hazards to the part or surrounding parts.

5.4.1 Qualification - During Phase B, we have examined the required qualification testing to assure that all parts are suitable for the VOYAGER Flight Capsule requirements. Qualification testing must be performed and will include all environments deemed necessary to qualify the parts. The particular number of qualification samples will be selected in accordance with individual parameters, environments and failure rate requirements. Qualification environment will include heat sterilization temperatures, decontamination (ETO) atmospheres, shock, humidity, vibration, acceleration and others necessary to assure compliance with VOYAGER requirements. Part parameter limits consist of attribute as well as variables data. The required testing is reflected in the part specifications.

The amount and degree of testing required is tempered by information acquired during previous programs or received from cooperating agencies, such as the Interservice Data Exchange Program (IDEP) and Parts Reliability Information Center/ Appollo Parts Information Center (PRINCE/APIC).

5.4.2 Screening - Our study has reconfirmed that screening is a prime requisite to assure reliability for a long life space program such as VOYAGER. Screening provides for the selection, from a group of parts, having the potential for the desired reliability. Screening is nondestructive testing performed on a lot-by-lot basis in an effort to:

a. Eliminate product degradation
b. Identify and control process changes (planned or unplanned)
c. Prevent anomalous failures
d. Identify and control design changes
e. Eliminate infant mortality
f. Isolate design discrepancies

We recommend, and are presently using, a screening technique for integrated circuit to control workmanship defects. A color photograph at 100X magnification of each device is required just prior to final seal. This is extremely effective, when combined with the usual 100% visual inspection requirement, in improving quality of the delivered parts. These photographs, identified with the part serial number, allow elimination of devices with scratched metalization, foreign particles and other common failure causes attributable to workmanship.

5.5 CONTROL - In the course of our study the following control elements (Part Material and Process Controls, Flow Chart Documentation, Approved Parts List - APL, APL addition/deletions procedures, traceability requirements) were determined as necessary to assure that only acceptable and qualified parts are used in the assembly of subsystem and systems. A discussion of these controls is found in Part C, Section 10, of Volume VI.

Our study recommendations on implementation of these controls, including traceability requirements, are noted below.

5.5.1 Part Manufacturer - The manufacturer of parts for VOYAGER Flight Capsule equipment is required to apply adequate controls to incoming inspection, materials, processes, fabrication, testing, stocking and packaging. A McDonnell requirement is that Reliability and Quality Assurance Plans (including as a minimum, organizational relationships with other departments in such matters as part design, failure rate prediction, failure mode identification, and design proof testing) be made available on request by the parts manufacturer for review.

On critical parts, the manufacturer is required to submit a flow chart which shows the entire processing from incoming materials to final part shipment. All processes and inspection points are identified by the applicable internal specification including revision date. Subsequent to acceptance of the flow chart, changes must be reported by the supplier before shipment of parts incorporating process changes. Although this requirement is not expected to prevent changes in the manufacturer's processes, it establishes a baseline upon which an evaluation can be made of process changes as they occur on parts procured after the initial qualification of the manufacturer. Single lot procurement is used where practicable by the subcontractors. (All parts required for the system are purchased at one time and are from the same lot as the qualification sample.)

5.5.2 Subcontractor - Subcontractors are subject to the same controls as those used internally at the prime contractor. The subcontractors are monitored to ensure conformance. Part selection by the subcontractor is limited to those parts included in the VOYAGER Approved Parts List established and maintained by the prime contractor. In order to use parts not on the approved list, a procedure for revising the Approved Parts List is discussed in Part C, Section 10 of Volume VI.

Subcontractors are required to keep McDonnell apprised of all part application and selection activities. This information, coupled with the prime contractor's own part experience, is disseminated to all subcontractors to minimize parallel effort and encourage consideration of parts already proven by test.

5.5.3 Traceability - Traceability requirements provide for the identification of a particular piece part or group of parts through all phases of assembly and testing. All parts will be identified with either a serial number or lot number. Serial numbers will be used on critical parts only and will be minimized to the greatest extent possible. The traceability document (207-780002) prepared during our Phase B activity, lists the following parts as requiring serialization.

Transistors - power, field effect and RF

Diodes - microwave, varactor, controlled rectifiers

Integrated circuits

Tubes

Crystals

All other parts will be identified by lot number for traceability.

Any failures or deficiencies are isolated to the part level and proper corrective action taken. All failed parts are subjected to failure analysis to determine failure modes. After failure modes are identified, an analysis of the test data will enable determination of the proper corrective action.

APPLICATION		QTY/ ASSY	FIN. ART.	REVISIONS			
NEXT ASSY	USED ON			LTR	DESCRIPTION	DATE	APPROVED
				A	Added Paragraph 5.5	18 July 1967	[signature]

CODE NO.	PART NO.	DRAWING OR SPECIFICATION	NOMENCLATURE OR DESCRIPTION	STOCK / VENDOR NAME - ADDRESS	MATL

PARTS LIST

LIMITS UNLESS NOTED .x = ±.1 .xx = ±.03 .xxx = ±.010	DRAWN J O'Montony 16 June 67	MCDONNELL ST. LOUIS, MO.		
	CHECK			
	STRENGTH	GENERAL SPECIFICATION VOYAGER FLIGHT CAPSULE SEMICONDUCTORS, TRANSISTORS, DIODES AND INTEGRATED CIRCUITS		
	GR ENGR			
	APPD			
FINISH SPEC	PROJ ENGR [signature]	SIZE A	CODE IDENT NO. 76301	207-780003
CONTRACT NO.	CUSTOMER	SCALE		SHEET 1 of 14

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1. SCOPE

1.1 This specification establishes the general requirements for semiconductor, transistors, diodes and integrated circuits suitable for use in Voyager Flight Capsule application. Specific requirements for a particular semiconductor device are listed in applicable detail part drawings.

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on the date of invitation for bids, form a part of this specification to the extent specified herein:

SPECIFICATIONS

Military

MIL-S-19500	Semiconductor Devices, General Specification
MIL-G-45204	Gold Plating (Electrodeposited)

National Aeronautics and Space Administration

NPC 200-3	Inspection system provisions for Suppliers of Space Materials, Parts, Components and Service

McDonnell

207-780011	Visual Inspection Criteria, Voyager Flight Capsule Semiconductor Devices

STANDARDS

Military

MIL-STD-130	
MIL-STD-202	Test Methods for Electronic and Electrical Component Parts
MIL-STD-750	Test Methods for Semiconductor Devices
MIL-STD-1276	Weldable Leads for Electronic Component Parts

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DRAWN	JDM	APPRD		GENERAL SPECIFICATION VOYAGER FLIGHT CAPSULE SEMICONDUCTORS, TRANSISTORS, DIODES AND INTEGRATED CIRCUITS.	REV	MODEL	VOL	ASSY NO.
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3. REQUIREMENTS

3.1 Conformance. The individual types of semiconductors shall conform to the detailed requirements specified in the applicable McDonnell detail part drawing and this specification.

3.1.1 Conflicting Requirements. In the event of conflict between this specification and the documents referenced herein, the order of precedence shall be as follows:

a. Purchase Order
b. Applicable McDonnell Detail Part Drawing
c. This Specification
d. NASA/Government Specification
e. Military Specifications.

3.1.2 Reference to Detail Part Drawing. For purposes of this specification, when the term "specified" or "as specified" is used without reference to a specific location the intended reference is to the McDonnell detail part drawing.

3.2 Qualification. Semiconductor devices furnished under this specification shall be a product which has been tested and passed the qualification and acceptance tests specified herein.

3.3 Request for Deviation. Any change from the requirements of this specification, or applicable documents listed herein, shall be considered a deviation. Request for a deviation shall be submitted in writing to McDonnell. Materials and processes used in the fabrication and assembly of the semi-conductor qualification test samples shall be documented at the time of qualification and any subsequent material and process changes for these parts shall be forwarded to McDonnell. Manufacturer shall obtain McDonnell approval before shipment of any parts for Voyager Flight Capsule application containing such changes.

3.4 Leads and Terminal Material/Finish. The lead material used shall conform to MIL-STD-1276, as applicable. The leads shall not show evidence of base metal corrosion after completion of the environmental tests specified herein.

The finish of the semiconductor case shall exhibit no peeling or cracking of the body surface area, of the marking, or of the color coding after completion of all tests performed thereon.

3.5 Mechanical Characteristics.

The mechanical characteristics of the semi-conductor shall be as specified herein and in the detail part drawing.

3.5.1 Lead and Terminal Test. Each semiconductor shall be capable of withstanding the pull test, bend test, twist test, torque test and soldering heat test as specified in the detail part drawing without physical damage to the leads, terminals or the semiconductor body, and without degradation of the semiconductor electrical characteristics.

3.6 Electrical. Semiconductor electrical performance characteristics shall be as specified in the detail part drawing. Semiconductors furnished to the requirements of this specification shall have met the qualification and acceptance inspections specified in 4.2 and 4.3.

3.6.1 Maximum Ratings. Semiconductor maximum ratings shall be as specified in the detail part drawing.

3.7 Environmental. Semiconductors shall operate within the limits as specified in the detail part drawing before and after being subjected to the environmental conditions outlined in 3.7.1 thru 3.7.11.

3.7.1 Sterilization and Decontamination. Semiconductors shall operate within the limits as specified in the detail part drawing after being subjected to heat sterilization and ethylene oxide decontamination.

3.7.1.1 Heat Sterilization. Sterilization shall consist of six separate cycles of heat at a maximum temperature of 135°C. in a nitrogen atmosphere. The nitrogen shall have an initial dew point prior to heating of no greater than minus 54°C and the gas shall possess a purity so that no more than 50 parts/million of extraneous products shall be contained within the gas. The total time of application of the environment is 96 hours per cycle (the time at the stabilized 135°C is 92 hours per cycle). Each item shall be at an initial temperature of 20-25°C prior to the beginning of each cycle. Performance tests and other evaluation criteria for determining the effects of the environment on the units shall be as specified in the detail part drawing.

3.7.1.2 Decontamination. Devices shall meet the end point test limits of group B sub-group 2 before and after the ethylene oxide decontamination test. This test shall consist of six (6) separate cycles at a temperature of 50 ± 5°C and an environment of 88% Freon and 12% ethylene oxide at 50% relative humidity and a concentration of 600 m.g./liter of gaseous atmosphere. A test cycle shall consist of:

a. 1 hour during which the temperature is increased to 50 ± 5°C and the air atmosphere is maintained at 50% R.H.
b. 21 to 24 minutes during which the atmosphere is evacuated to 70 torr.

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3.7.1.2 (Continued)

c. 27.5 hours during which the atmosphere is maintained at 50% R.H. with a concentration of 600 m.g./liter of 88/12 mixture of Freon 12 and ethylene oxide.
d. 15 minutes - evacuate to 70 torr. and permit temperature to fall.
e. 45 minutes - permit temperature to fall to 20-25°C by introducing ambient air.

3.7.2 High Temperature Storage. Semiconductors shall operate within the limits specified in the detail part drawing after being tested in accordance with Method 1031.1 of MIL-STD-750. The ambient temperature for this test shall be 200°C minimum.

3.7.3 Temperature Cycling. Semiconductors shall operate within the limits as specified in the detail part drawing after being tested in accordance with Method 1051.1 of MIL-STD-750 (Test Condition C, Method 107 of MIL-STD-202)

3.7.4 Moisture Resistance. Semiconductors shall operate within the limits as specified in the detail part drawing after being tested in accordance with Method 1021.1 of MIL-STD-750 (Method 106, MIL-STD-202, omitting Step 7B and the initial 24 hour soak period.)

3.7.5 Hermetic Seal. Semiconductor shall not exhibit leak rates in excess of 1×10^{-8} atm - cc per second when tested in accordance with 4.3.3.4.

3.7.6 Shock. Semiconductors shall be capable of operation within the limits as specified in the detail parts drawing after being tested in accordance with Method 2016.1 of MIL-STD-750. A total of 30 impacts shall be applied in each of three mutually perpendicular planes (10 impacts each plane).

3.7.7 Vibration. Semiconductors shall be capable of operation within the limits specified in the detail part drawing when subjected to the Vibration Test Method 2046 of MIL-STD-750.

3.7.8 Low Temperature Operating. Semiconductors shall be capable of operating within the limits as specified in the detail part drawing after stabilizing parts at an ambient temperature -63^{+0}_{-5}°C for this test.

3.7.9 Acceleration. Semiconductors shall be capable of operation within limits as specified in the detail part drawing after subjected to a constant acceleration of 20,000g's per Method 2006 of MIL-STD-750, with the semiconductors so oriented that the acceleration vector is in the direction (normally in Y_1 orientation only) most likely to produce mechanical/bonded interconnection failure.

3.7.10 Vacuum. Semiconductors shall be capable of operation within limits as specified in the detail part drawing after subjected to a pressure of 10^{-5} Torr (mm of mercury) at a temperature of -65°C ± 5°C for a period of 24 hours. No degradation or deteriorations of seal shall occur.

3.7.11 Operating Life. Semiconductors shall be capable of operation within limits as specified in the detail part drawing when tested in accordance with Method 1026.1 of MIL-STD-750.

3.8 Failure Rate. Semiconductors shall have a failure rate as specified in the detail part drawing.

3.9 Physical Dimensions. The physical dimensions of the semiconductors shall be as specified in the detail part drawing.

3.10 Marking. Manufacturer shall permanently and legibly mark each part in accordance with MIL-STD-130 with the following:

- Manufacturer's Name or Symbol
- Lot or Serial Number (as specified)
- Polarity (as applicable)

3.11 Part Identification/Traceability. Two-way traceability, that is, from a particular semiconductor to a known lot and from a known lot to a particular semiconductor from that lot shall be maintained when specified in the detail part drawing. This information shall be immediately available to McDonnell upon request. Part identification for this two-way traceability shall include part serialization per 3.11.1. Where this two-way traceability defined above is not required to a particular semiconductor, lot identification shall be provided as a minimum per 3.11.2.

3.11.1 Part Serialization. Semiconductors when required shall be marked with an individual serial number. The serial number shall consist of a three digit number ranging from "000" to "999" for each semiconductor part number. Deviations to this range of serial numbers will be considered and approved (by McDonnell) as justified. The serial numbers shall identify each semiconductor with the applicable recorded data and manufacturer's lot or lots. No serial number shall be duplicated for semiconductors with the same part number. The serial number shall be printed on the semiconductor body (or as specified on the detail part drawing).

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3.11.2 Lot Identification. Each semiconductor not requiring part serialization shall contain the manufacturer's lot identification number which shall identify the semiconductor with the applicable recorded data for a particular group or lot of parts included under the identifying lot number. A manufacturer's lot is defined as a quantity of parts produced in one week or less, from a single production line using the same design, materials, manufacturing processes and specifications, and presented to inspection for tests at the same time. A McDonnell Voyager Flight Capsule lot shall be the group of parts to be subjected to the acceptance inspection specified in 4.3. The lot of parts purchased to this specification shall be from a single manufacturer's lot except where deviations have been submitted and approved.

3.12 Documentation and Data Submittal. The variables data listed under (a) and (b) below shall be submitted with the semiconductor. In the addition to the parameter values, the punched card shall contain the individual semiconductor lot number or serial number, McDonnell part number, date, etc. Data recorded regarding a rejected McDonnell lot shall be forwarded to the McDonnell Company. A copy of all required data shall be kept on file by the manufacturer for a period of at least five years from the date of delivery of the components. At the completion of the test specified in 4.3.4 the component inspection report form per Figure 1 shall be completed and submitted with each shipment of parts and data cards. Data submittal shall include the following:

(a) Variables data on each of the critical parameters specified at the 100% level for each semiconductor given the acceptance inspection per 4.3.

(b) Variables data on all parameters specified in the applicable detail part drawing taken during final electrical measurements (post burn-in) final electrical inspection (Group A inspection).

(c) Data on all parameters specified in the applicable detail part drawing following the Group B environment test per 4.3.7.

4. RELIABILITY AND QUALITY ASSURANCE PROVISIONS

4.1 General. Implementation of the quality assurance provisions specified herein shall be in accordance with the applicable requirements of NPC 200-3. The examination and testing of semiconductor devices shall be classified as follows:

(a) Qualification Inspection

(b) Acceptance Inspection

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4.2 Qualification Inspection. Qualification tests are those tests performed on devices to verify conformance to all requirements of this specification. Unless otherwise specified the total qualification test sample shall consist of 60 specimens which have not been previously subjected to life testing. The specimens shall be subjected to the 100% Process Preconditioning and Screening, the group A and B tests and the failure rate life test of the detail specification, as follows: All specimens shall be subjected to 100% Process-Preconditioning and Screening, Group A tests and the Failure Rate Life Test. For group B, testing the specimens shall be divided into three groups of 20 specimens each. The first group shall be subjected to the tests specified in Sub-group 1 and 2 of Group B; the second group shall be subjected to the tests specified in sub-group 3 of Group B; the third group shall be subjected to the tests specified in the remaining sub-group of Group B.

4.2.1 Post Qualification Test End Points - The end point tests specified in the individual detail specification shall be performed after the intermittent life test and after each Group B sub-group test where end points are specified. Failure of one device in one or more tests of a given sub-group will be charged as a single failure. Failures in excess of those allowed for each group shall constitute qualification failure. Devices subjected to qualification inspection may be shipped except for destructive tests which include solderability,soldering heat, moisture resistance, terminal strength, salt atmosphere and salt spray. Compliance with these requirements qualifies the manufacturer for the following 12 month period provided design changes are not made during this time.

4.3 Acceptance Inspection. Acceptance Inspection. Acceptance inspection consists of the following inspections:

(a) Dimensional

(b) Visual

(c) 100% Process-Preconditioning and Screening (Burn-in)

(d) Group A Electrical

(e) X-ray (diodes and transistors); Color (Micro-Photographs (Integrated Circuit - see 4.3.7)

(f) Group B Environmental

Electrical measurement methods shall conform to the applicable requirements of MIL-STD-750. The McDonnell Outside Production Quality Assurance Department shall be notified at least one week in advance of the scheduled date for performing acceptance inspection on semiconductors purchased to this

4.3 Acceptance Inspection (Continued)

specification. Lots which are rejectable via sampling inspection may be screened 100 percent for the failing characteristics and may then be resubmitted one time to inspection. In addition, McDonnell reserves the right to sample test each 100 percent inspection requirement for each lot to a 2 percent LTPD level and reject any lot that does not meet the requirement. The 100 percent process-preconditioning and screening tests in 4.3.3 are not required to be repeated when they are already included in the manufacturers normal production processing.

4.3.1 Dimensional Inspection. Dimensional inspection shall be performed on the semiconductors at an LTPD of 15 percent as specified (Ref. Table I for minimum requirements).

4.3.2 Visual Inspection. Visual inspection shall be performed at a 100 percent level as specified in the detail part drawing and specification 207-780011 as applicable. Semiconductors not meeting the visual inspection criteria shall be rejected. Integrated circuits shall be micro-photographed in color, per 4.3.7.

4.3.3 100% Process-Preconditioning and Screening. The semiconductors in the lot shall be subjected to the following tests. The test methods employed shall be in accordance with MIL-STD-750. The environmental tests shall be performed prior to the burn-in inspection of 4.3.3.7. Test 4.3.3.1 thru 4.3.5 shall be performed in the following sequence.

4.3.3.1 High Temperature Storage. The semiconductors shall be subjected to a high temperature storage per MIL-STD-750, Method 1031.1 at a temperature of 200°C minimum.

4.3.3.2 Temperature Cycling. The semiconductors in the lot shall be temperature cycled in accordance with MIL-STD-750, Method 1051.1 (MIL-STD-202, Method 107B, Test Condition C).

4.3.3.3 Constant Acceleration. The semiconductor shall be subjected to constant acceleration in accordance with MIL-STD-750, Method 2006. A minimum centrifugal acceleration of 20,000g's shall be applied, with the semiconductor so oriented that the acceleration vector is in the Y_1 axis direction (or that axis which will most likely produce mechanical bonded interconnection failure).

4.3.3.4 Hermetic Seal Tests

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4.3.3.4.1 Gross Leaks. Each semiconductor shall be tested in accordance with MIL-STD-202, Method 112, Test Condition A. Any indication of air escapement from within the semiconductor case shall be cause for device rejection.

4.3.3.4.2 Fine Leak. Each semiconductor and metal cased diode shall be tested in accordance with MIL-STD-202, Method 112, Test Condition C, Procedure IIIA or IIIB. Semiconductors with leak rates in excess of 10^{-8} atm-cc per second shall be rejected.

4.3.3.4.3 Glass Diode Seal Test. Each glass cased diode shall be subject to an hydraulic pressure of 100 psig in a solution of isopropyl alcohol with coloring dye for two hours. Following pressurization, rinsing, and drying, each diode shall receive a reverse current test and an operating vibration test (see 4.3.3.5). The time interval between pressurization test completion and start of the electrical tests shall be at least two hours, but not to exceed eight hours. Diodes exhibiting reverse leakage in excess of the limits specified in the detail part drawing, ionic contamination (indicated by mobile hysteresis progressing in the high current direction) or dye penetration shall be rejected.

4.3.3.5 Operating - Vibration Test. Where specified, each semiconductor shall be subjected to a simple harmonic vibration having a minimum of 0.1 inch double amplitude displacement at a frequency of 60 $\pm$ 2 cps for a minimum period of 30 seconds. During vibration continuously monitor the reverse characteristic, swept at 60 cps, to the inverse current or voltage specified. Devices displaying flutter, drift, dynamic instabilities or shift in trace shall be rejected.

4.3.3.6 Pre-Burn-In Electrical Measurements. Each semiconductor in the Voyager Flight Capsule lot shall be subjected to electrical measurements of the critical parameters (100% level) specified in the applicable detail part drawing. All variable data shall be recorded.

4.3.3.7 Burn-In Operational Life Test. Each semiconductor shall be subjected to a burn-in (operational life test) at the electrical level and temperature for 168 hours as specified in the detail part drawing.

4.3.3.8 Post Burn-In Electrical Measurements. Same as pre-burn electrical measurements except that limits including delta or parameter incremental changes shall be as specified in the detail part drawing.

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4.3.4 Group A Electrical Inspection. Group A electrical inspection shall be performed by lot sample as specified in the Group A inspection, Table II of the applicable detail part drawing. The minimum sample size to assure a Lot Tolerance Percent Defective (LTPD) specified with 90% confidence for various failure acceptance numbers (a) is shown in Table I of this specification. The rejection number (r), equals a + 1. The acceptance sample size required to assure the specified LTPD shall be selected from Table I of this specification by the manufacturer.

4.3.5 Final Visual Inspection. Final visual inspection shall be performed at a 100 percent level. Only those semiconductors which meet the visual inspection criteria specified shall be shipped.

4.3.6 X-ray Examination. Unless otherwise specified in the detail part specification, each transistor and diode not permitting internal visual inspection shall be photographed using an X-ray machine of sufficient power to show the internal construction. Integrated circuits shall be micro photographed per 4.3.7. Sufficient definition is achieved when free particles of solder or other foreign matter one mil in diameter can be determined. A series of x-ray photographs shall be taken perpendicular to the longitudinal axis (in two mutually perpendicular planes). The x-ray photographs shall be identified to assure traceability to the individual semiconductor when part serialization is required. Acceptance criteria shall be in accordance with McDonnell 207-780011.

4.3.7 Photographic Records. Each integrated circuit shall be photographed at 100X magnification, in color, just prior to final seal. Photographs shall be identified with device part number and serial number and delivered with the devices. Photographs shall have sufficient resolution to show scratches in the conductor paths, particle inclusions, etc.

4.3.8 Group B Environmental Inspection. Semiconductor parts from the same lot to be shipped per this specification shall be sample tested as specified in the Table III Group B Inspection of the applicable detail part drawing.

4.4 Failure Accountability. A complete accounting of failures and modes (i.e., human error, instrumentation, parametric, or catastrophic) shall be submitted to McDonnell on all accountable and unaccountable failures occurring during acceptance inspection.

5. PREPARATION FOR DELIVERY

5.1 Unit Packaging. The semiconductors shall be individually packaged to protect the case and leads during shipment. Each unit package shall be clearly marked as to semiconductor types, serial number and lot number. Package design shall be subject to McDonnell approval prior to usage by the manufacturer.

DRAWN	JM	APPRD			GENERAL SPECIFICATION VOYAGER FLIGHT CAPSULE SEMICONDUCTORS, TRANSISTORS, DIODES AND INTEGRATED CIRCUITS	REV	MODEL	VOL	ASSY NO.
CHECK		APPRD							
APPRD		APPRD			MCDONNELL ST. LOUIS, MO.	DRAWING NO. 207-780003			SHEET 11

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5.2 **Packaging of Shipping Containers.** The unit packages shall be packed in the shipping containers in a manner to provide maximum protection from shock and vibration during transit; and in the order of ascending serial number or groups of serial numbers, to facilitate and minimize handling subsequent to delivery.

5.3 **Marking of Shipping Containers.** Each shipping container shall be marked with the manufacturer's name, part designation number, date code and lot number.

5.4 **Shipping/Data Documentation.** The certificate of compliance and the data required in 3.12, 4.3 and 4.4 shall accompany each shipment of parts. The IBM cards shall be punched and interpreted, and packed in numerical sequence in suitable boxes, labeled as to component type, lot number and serial number range. The data cards for rejected parts shall be segregated from the cards for accepted parts and all cards submitted with the lot. For integrated circuits the photographs required in Paragraph 4.3.7 shall also accompany the shipment.

5.5 **Process Flow Chart Documentation.** The vendor shall submit to McDonnell for acceptance a flow chart showing the entire processing from incoming materials to final shipment. All processes and inspection points shall be identified by the applicable internal specification numbers to include revision and date. The disposition of this documentation shall also be indicated. Subsequent to McDonnell acceptance, changes must be reported to McDonnell before shipment of parts.

6. **NOTES.** Not applicable.

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DRAWN	Jd M	APPRD			GENERAL SPECIFICATION VOYAGER FLIGHT CAPSULE SEMICONDUCTORS, TRANSISTORS, DIODES AND INTEGRATED CIRCUITS	REV A	MODEL	VOL	ASSY NO.
CHECK		APPRD							
APPRD		APPRD			MCDONNELL ST. LOUIS, MO.	DRAWING NO. 207-780003			SHEET 12

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Lot Number______	Specification______
Part Number______	P. O. Number______
Manufacturer______	Date Received______
Lot Size______	Sample Size______
Quantity Accepted______	Date Completed______
Quantity Rejected______	Lot Disposition______
Date Code______	Part Description______
Lot S/N Range______	Sample S/N Range______

	Tests Performed	No. Rejects Initial Meas.	Date	No. Rejects 2nd Meas.	Date	No. Rejects 3rd Meas.	Date	Insp. Stamp
1	Initial visual							
2								
3								
4								
5								
6								
7								
8								
9	Final Visual							

Serial Numbers of Rejected Parts

Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9
Remarks:								

____

Quality Assurance Manager

Figure 1. Sample Component Inspection Report Form

DRAWN		APPRD	GENERAL SPECIFICATION VOYAGER FLIGHT CAPSULE SEMICONDUCTORS, TRANSISTORS DIODES AND INTEGRATED CIRCUITS	REV	MODEL	VOL	ASSY NO.
CHECK		APPRD					
APPRD		APPRD	MCDONNELL ST. LOUIS, MO.	DRAWING NO. 207-780003			SHEET 13

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TABLE I

Minimum Sample Size to be Tested to Assure an LTPD for Small Lot Quantities

Maximum LTPD	15	10	5	1
Acceptance Number	**Minimum Sample Size**			
0	17	22	45	231
1	28	38	77	390
2	38	52	105	533
3	49	65	132	668
4	58	78	159	798
5	68	91	184	927
6	77	104	210	1054
7	87	116	234	1178
8	95	128	258	1300
9	104	140	282	1421
10	113	152	307	1541

APPROVED JUNE 1967 REVISED

DRAWN		APPRD			GENERAL SPECIFICATION VOYAGER FLIGHT CAPSULE SEMICONDUCTORS, TRANSISTORS DIODES AND INTEGRATED CIRCUITS	REV	MODEL	VOL	ASSY NO.
CHECK		APPRD							
APPRD		APPRD			MCDONNELL ST. LOUIS, MO.	DRAWING NO. 207-780003			SHEET 14

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APPLICATION		QTY/ ASSY	FIN. ART.	REVISIONS			
NEXT ASSY	USED ON			LTR	DESCRIPTION	DATE	APPROVED

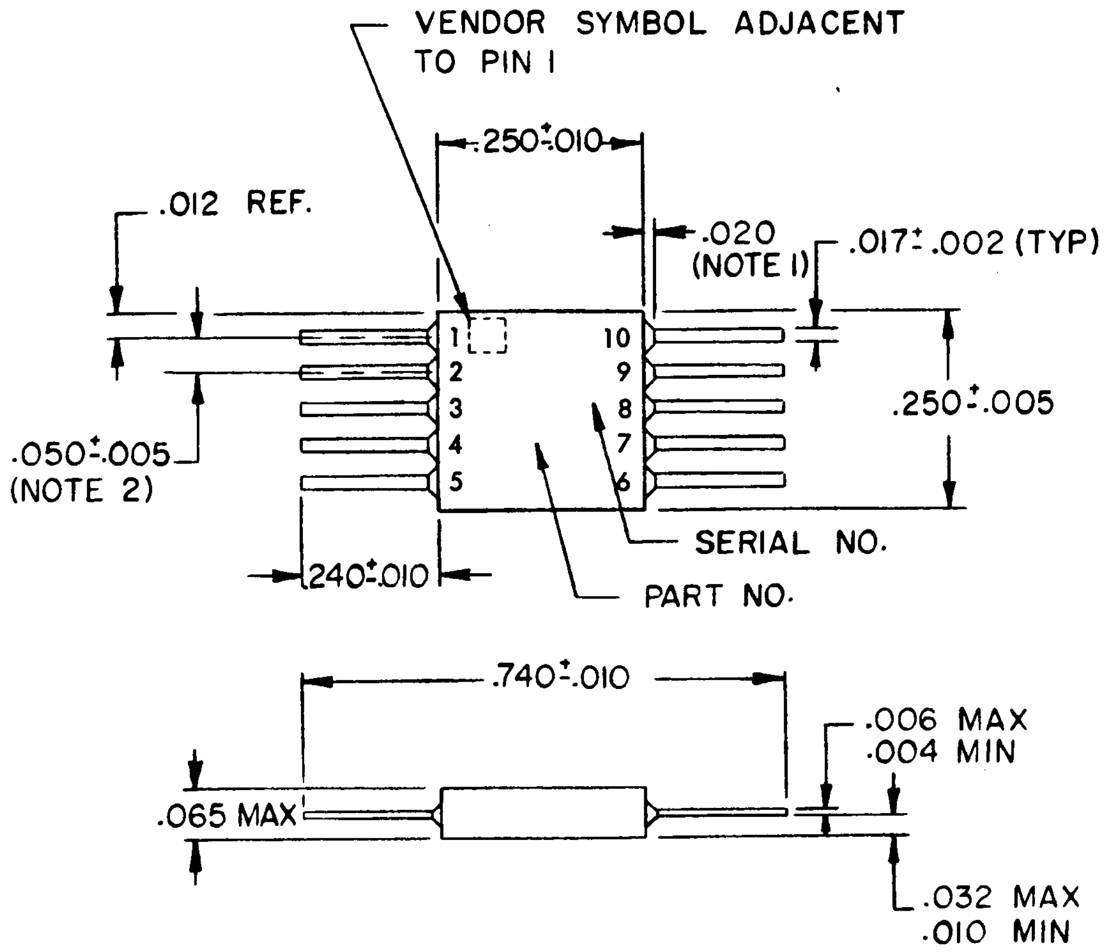
DETAIL PART DRAWING

CODE NO.	PART NO.	DRAWING OR SPECIFICATION	NOMENCLATURE OR DESCRIPTION	STOCK / VENDOR NAME - ADDRESS	MATL

PARTS LIST

LIMITS UNLESS NOTED .x = ±.1 .xx = ±.03 .xxx = ±.010	DRAWN J.D. Montenye 24 June 67 CHECK STRENGTH GR ENGR APPD	MCDONNELL ST. LOUIS, MO. INTEGRATED CIRCUIT FLIP FLOP, RST		
FINISH SPEC	PROJ ENGR [signature] 17 July 67	SIZE A	CODE IDENT NO. 76301	207-780007
CONTRACT NO.	CUSTOMER	SCALE		SHEET 1 OF 15

MAC 1197A (REV 24 NOV 65)



Notes:

1. Lead spacing dimensions apply in this area only.
2. Tolerances are noncumulative.
3. Pin numbers for reference only and do not appear on part.

REVISED:	DRAWN		APPRD			INTEGRATED CIRCUIT FLIP FLOP, RST	REV	MODEL	VOL	ASSY NO.
	CHECK		APPRD				DRAWING NO.			SHEET
	APPRD		APPRD			MCDONNELL ST. LOUIS, MO.	207-780007			2

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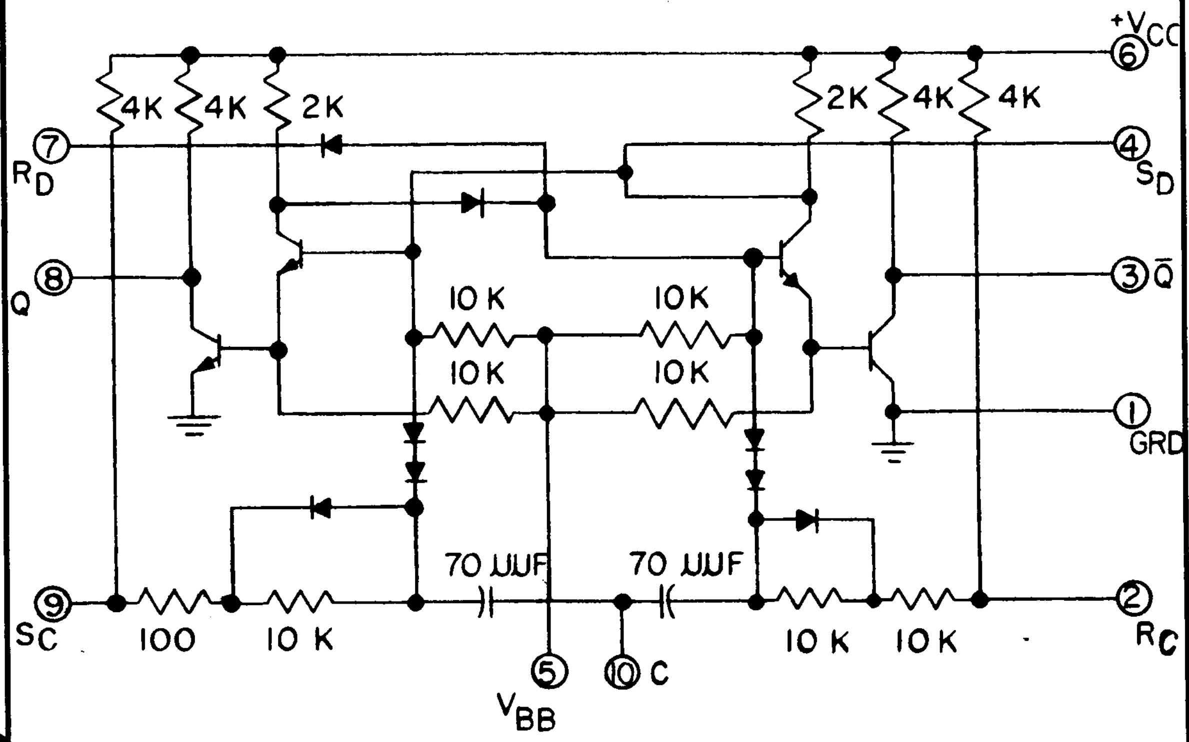
CODE IDENT NO. 76301



SCHEMATIC DIAGRAM

DRAWN			APPRD			INTEGRATED CIRCUIT FLIP FLOP, RST	REV	MODEL	VOL	ASSY NO.
CHECK			APPRD							
APPRD			APPRD			MCDONNELL ST. LOUIS, MO.	DRAWING NO. 207-780007			SHEET 3

REVISED:

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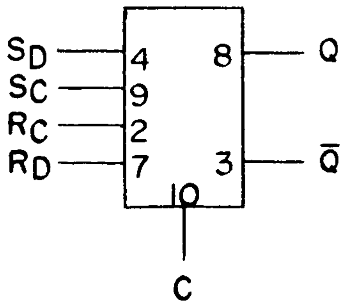
CODE IDENT NO. 76301



Logic Diagram

Clocked Set-Reset			Direct Set-Reset		
S_C	R_C	Q	S_D	R_D	Q
0	0	?	0	0	$\triangle 1$
0	1	1	0	1	1
1	0	0	1	0	0
1	1	No Change	1	1	No Change

Truth Table

Positive Logic Definitions: High Voltage = 1
Low Voltage = 0

$\triangle 1$ Both Q and $\overline{Q}$ in 1 state until either S_D or R_D rises

Clocked set-reset Q is the logic state after the first negative going edge of the clock pulse at pin 10 with initial conditions before clock pulse at S_C and R_C as shown.

Table I, Maximum Ratings (25°C)

Characteristic	Min.	Max.	Unit
Input Voltage (Pins 2, 3, 4, 7, 8, 9, 10)	0	+ 8	V
Output Voltage (Pins 3, 8)	0	+ 8	V
Vcc (Pin 6)	0	+8.2	V
Vbb (Pin 5)	0	- 8	V
Input Current (Pins 2, 3, 4, 7, 8, 9, 10)	- 30	+ 30	MA
Output Current (Pins 3, 8)	-100	+100	MA
Operating Temperature	- 55	+125	°C
Storage Temperature	- 65	+175	°C
Power Dissipation	——	150	MW

DRAWN		APPRD		INTEGRATED CIRCUIT FLIP FLOP, RST	REV	MODEL	VOL / ASSY NO.
CHECK		APPRD					
APPRD		APPRD		MCDONNELL ST. LOUIS, MO.	DRAWING NO. 207-780007		SHEET 4

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Notes:

1. General

   1.1 These parts shall be specified, procured and used under the McDonnell approved part number 207-780007 (any vendor part number is for reference only).

   1.2 These parts shall meet all requirements of McDonnell drawing 207-78003 except as noted herein.

   1.3 All tests and measurements shall be performed at a temperature of 25 ±2°C unless otherwise specified.

   1.4 All symbols and abbreviations shall be as defined in MIL-S-19500.

   1.5 All voltage and capacitance measurements are referenced to ground unless noted. Positive current flow is defined as into the pin referenced. Pins not specifically referenced are left open.

2. Requirements

   2.1 Electrical

      2.1.1 Performance characteristics shall be as specified in Table II (Group A) and Table IV (Group B) inspections.

      2.1.2 The maximum electrical ratings shall be as specified in Table I when operated at an ambient temperature of 25°C.

   2.2 Mechanical

      2.2.1 Each device shall be of the design, construction and physical dimensions specified herein.

      2.2.2 Leads shall be in accordance with MIL-STD-1276, Type K.

      2.2.3 Devices shall be monolythic, planar passivated construction.

   2.3 Environmental

      2.3.1 Devices shall meet the end point test limits of Group B, Subgroup 2 before and after the sterilization heat test (6 cycles) per paragraph 3.7.1.1 of 207-780003.

REVISED:

DRAWN			APPRD			INTEGRATED CIRCUIT FLIP FLOP, RST	REV	MODEL	VOL	ASSY NO.
CHECK			APPRD							
APPRD			APPRD			MCDONNELL ST. LOUIS, MO.	DRAWING NO. 207-780007			SHEET 5

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2.3 Environmental (Continued)

2.3.2 Devices shall meet the end point test limits of Group B, Subgroup 2 before and after the ethylene oxide decontamination test (6 cycles) per paragraph 3.7.1.2 of 207-780003.

2.4 Failure Rate

2.4.1 The qualification approval devices shall demonstrate a maximum failure rate of 1.0 percent per 1,000 hours at 90 percent confidence level. Failures are defined as devices which do not meet the Table III (Group A) inspection requirements. During the life test, the devices shall be operated at $T_A = 125 \pm 2^{\circ}C$, dynamic operation at $100KH_z$ in the circuit described in test circuit Figure 3.

2.5 Marking

2.5.1 Each device shall be permanently and legibly marked per McDonnell specification 207-780003, paragraph 3.10 with the following:

- Manufacturer's name or symbol
- Serial number in accordance with McDonnell specification 207-780003, paragraph 3.11
- McDonnell part number.

2.6 Quality Assurance

2.6.1 Qualification inspection shall consist of the examinations and tests specified in Tables II, III and IV in addition to the failure rate inspection of paragraph 2.4.

2.6.2 Acceptance inspection shall consist of the examinations and tests of Table II 100 percent process preconditioning and screening and Table III (Group A) inspections.

DRAWN		APPRD			INTEGRATED CIRCUIT FLIP FLOP, RST	REV	MODEL	VOL	ASSY NO.
CHECK		APPRD							
APPRD		APPRD			MCDONNELL ST. LOUIS, MO.	DRAWING NO. 207-780007			SHEET 6

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2.6 Quality Assurance (Continued)

2.6.3 Each device shall be photographed at 100X magnification, in color, just prior to final seal. Photographs shall be identified with device part number and serial number and delivered with the devices. Photographs shall have sufficient resolution to show scratches in conductor path, particle inclusions, etc.

2.7 Preparation for Delivery

2.7.1 Devices shall be prepared for delivery in accordance with McDonnell specification 207-780003, paragraph 5.

DRAWN		APPRD			INTEGRATED CIRCUIT FLIP FLOP, RST	REV	MODEL	VOL	ASSY NO.
CHECK		APPRD							
APPRD		APPRD			MCDONNELL ST. LOUIS, MO.	DRAWING NO. 207-780007			SHEET 7

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Table II 100% Process-Preconditioning and Screening

Examination or Test	MIL-STD-750 Method	MIL-STD-750 Conditions	Limits Min.-Max.	Units
Subgroup 1				
Photograph		Paragraph 2.6.3		
High Temperature Storage	1031	$T_A = 200 {}^{+10}_{-0}$ °C		
Temperature Cycling	1051	Condition C		
Constant Acceleration	2006	30,000 g, Y_1 Axis		
Seal				
Fine Leak		MIL-STD-202, Method 112C Condition C, Procedure IIIa	5×10^{-8}	cc/sec.
Gross Leak		MIL-STD-202, Method 112C Condition A, Ethylene Glycol		
Subgroup 2			PDA-10	
Power Burn In	1026	$T_A = 125 {}^{+10}_{-0}$ °C t = 168 Hours Dynamic Operation at 100Khz (Fig. 3)		
End Points		Per Group A, Subgroup 3		
"1" Output Voltage (V3,V8)			± 20% of Initial Value	
"0" Input Voltage (V4,V7,V10)			± 20% of Initial Value	
"0" Output Voltage (V3,V8)			± 0.1V	
"1" Input Current (I4,I7,I10)			10 Times Initial Value	

DRAWN		APPRD			INTEGRATED CIRCUIT FLIP FLOP, RST	REV	MODEL	VOL	ASSY NO.
CHECK		APPRD							
APPRD		APPRD			MCDONNELL ST. LOUIS, MO.	DRAWING NO. 207-780007			SHEET 7a

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Table III Group A Tests

Examination or Test	Test Conditions (V6 = 4.0V, V5 = -2.0V, V1 = Ground unless otherwise noted)	Measurement Terminal	LTPD	Limits Min.	Limits Max.	Units
Subgroup 1			*			
Visual and Mechanical Examination	MIL-STD-750 Method 2071					
Subgroup 2	$T_A = 25 \pm 2^{\circ}C$					
Input Voltage (Breakdown)			1			
BVS_D	I4 = 10mA	V 4		8.0	-	V
BVR_D	I7 = 10mA	V 7		8.0	-	V
BVC	I10 = 10mA	V10		8.0	-	V
Power Consumption						
Icc	Tie V9 to V8, Tie V2 to V3	V 6		-	6.00	mA
Output Voltage						
BVQ	V6 = 8.2V, V4 = 0V	V 8		8.0	-	V
$BV\bar{Q}$	V6 = 8.2V, V7 = 0V	V 3		8.0	-	V
Subgroup 3						
"1" Output Voltage			*			
VQ_1	V4 = 0.6V	V 8		3.9	-	V
$V\bar{Q}_1$	V7 = 0.6V	V 3		3.9	-	V
"0" Output Voltage						
VQ_0	V4 = 1.7V, V7 = 0, I8 = +16mA	V 8		-	0.40	V
$V\bar{Q}_0$	V4 = 0, V7 = 1.7V, I3 = +16mA	V 3		-	0.40	V
"0" Input Current						
IS_{D0}	V4 = 0, V7 = 0	I 4		- 0.5	- 1.40	mA
IR_{D0}	V4 = 0, V7 = 0	I 7		- 0.5	- 1.40	mA
IR_{C0}	V10 = 0, V2 = 0	I 2		- 0.5	- 1.40	mA
IS_{C0}	V10 = 0, V9 = 0	I 9		- 0.5	- 1.40	mA
"1" Input Current						
IS_{D1}	V4 = 5.0V	I 4		-	100.00	nA
IR_{D1}	V7 = 5.0V	I 7		-	100.00	nA
IC_1	V10 = 5.0V, V9 = 0, V2 = 0	I10		-	100.00	nA

DRAWN		APPRD			INTEGRATED CIRCUIT FLIP FLOP, RST	REV	MODEL	VOL	ASSY NO.
CHECK		APPRD							
APPRD		APPRD			MCDONNELL ST. LOUIS, MO.	DRAWING NO. 207-780007			SHEET 8

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CODE IDENT NO. 76301

Table III Group A Tests (Continued)

Examination or Test	Test Conditions (V6 = 4.0V, V5 = -2.0V, V1 = Ground unless otherwise noted)	Measurement Terminal	LTPD	Limits Min.	Limits Max.	Units
Subgroup 4	$T_A = +125 {}^{+10}_{-0}$ °C		1			
"1" Output Voltage						
VQ_1	V4 = .60V	I 8		3.8	-	V
$V\bar{Q}_1$	V7 = .60V	I 3		3.8	-	V
"0" Output Voltage						
VQ_0	V4 = 1.7V, V7 = 0V, I8 = 16mA	I 8		-	.45	V
$V\bar{Q}_0$	V4 = 0V, V7 = 1.7V, I3 = 16mA	I 3		-	.45	V
"1" Input Current						
IS_{D1}	V4 = 5.0V	V 4		-	10.00	uA
IR_{D1}	V7 = 5.0V	V 7		-	10.00	uA
IC_1	V10 = 5.0V, V9 = 0V, V2 = 0			-	10.00	uA
Subgroup 5	$T_A = -55 {}^{+0}_{-10}$ °C		1			
"1" Output Voltage						
VQ_1	V4 = 0.6V	V 8		3.9	-	V
$V\bar{Q}_1$	V7 = 0.6V	V 3		3.9	-	V
"0" Output Voltage						
VQ_0	V4 = 1.7V, V7 = 0V, I8 = 16mA	V 8		-	0.40	V
$V\bar{Q}_0$	V4 = 0V, V7 = 1.7V, I3 = 16mA	V 3		-	0.40	V
Subgroup 6	$T_A = +25 \pm 2$ °C		1			
Clocked mode switching level	Test Circuit Figure 1	-		-	1.00	V
Clocked mode holding level	Test Circuit Figure 1	-		3.4	-	V
Clocked mode turn on delay	Test Circuit Figure 2	-		15.0	40.00	ns
Clocked mode turn off delay	Test Circuit Figure 2	-		10.0	40.00	ns

* 100 percent inspection

DRAWN		APPRD			INTEGRATED CIRCUIT FLIP FLOP, RST	REV	MODEL	VOL	ASSY NO.
CHECK		APPRD							
APPRD		APPRD			MCDONNELL ST. LOUIS, MO.	DRAWING NO. 207-780007			SHEET 9

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Table III Group B Tests

Examination or Test	MIL-STD-750 Method	MIL-STD-750 Conditions	LTPD	Limits
Subgroup 1			15	
Physical Dimensions	2066			
Subgroup 2			15	
D.C. Parameters		Per Group A, Subgroup 3		
Solderability	2026	All Terminals		
Temperature Cycling	1052	10 Cycles T Max. = + 175°C		
Thermal Shock	1056	T Min. = - 70°C, T Max. = + 100°C		
Moisture Resistance	1021	Omit Initial Conditioning		
Heat Sterilization		Per Paragraph 2.3.1		
Ethylene Oxide Decontamination		Per Paragraph 2.3.2		
End Points		Ref. Group A, Subgroup 3		
"1" Input Current				10 Times Initial Value
"1" Output Voltage				± 20% Initial Value
"0" Input Current				± 20% Initial Value
"0" Output Voltage				± 0.1V
Subgroup 3			15	
D.C. Parameters		Per Group A, Subgroup 3		
Shock	2016	1500 g, 5 Blows, Each $X_1 \cdot Y_1 \cdot Z_1$ .05ms		
Vibration Fatigue	2046	30 g, Non Operating		
Vibration Variable Frequency	2056	30 g		
Constant Acceleration	2006	30,000 g, 1 Min., Each $X_1 \cdot Y_1 \cdot Z_1$		
End Points				
"1" Input Current				10 Times Initial Value
"1" Output Voltage				± 20% Initial Value
"0" Input Current				± 20% Initial Value
"0" Output Voltage				± 0.1V
Subgroup 4			15	
Terminal Strength	2036	Test Condition E, Weight 4 Oz.		

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DRAWN		APPRD			INTEGRATED CIRCUIT FLIP FLOP, RST	REV	MODEL	VOL	ASSY NO.
CHECK		APPRD							
APPRD		APPRD			MCDONNELL ST. LOUIS, MO.	DRAWING NO. 207-780007			SHEET 10

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CODE IDENT NO. 76301

Table III Group B Tests (Continued)

Examination or Test	MIL-STD-750 Method	MIL-STD-750 Conditions	LTPD	Limits
Subgroup 5			$\lambda = 5$	
D.C. Parameters		Per Group A, Subgroup 3		
High Temperature Life	1031	Non Operation, 1000 Hours		
End Points		T Min. = 150°C		
"1" Input Current				10 Times Initial Value
"1" Output Voltage				± 20% Initial Value
"0" Input Current				± 20% Initial Value
"0" Output Voltage				± 0.1V
Subgroup 6			$\lambda = 5$	
D.C. Parameters		Per Group A, Subgroup 3		
Operating Life	1026	1000 Hours, T Min. = +125°C		
		Dynamic Operation at 100 KC		
		Test Circuit 3		
End Points				
"1" Input Current				10 Times Initial Value
"1" Output Voltage				± 20% Initial Value
"0" Input Current				± 20% Initial Value
"0" Output Voltage				± 0.1V

DRAWN		APPRD			INTEGRATED CIRCUIT FLIP FLOP, RST	REV	MODEL	VOL	ASSY NO.
CHECK		APPRD				DRAWING NO. 207-780007			SHEET 11
APPRD		APPRD			MCDONNELL ST. LOUIS, MO.				

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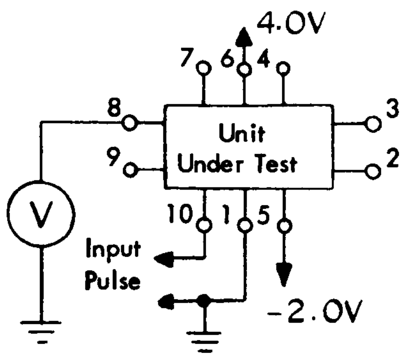
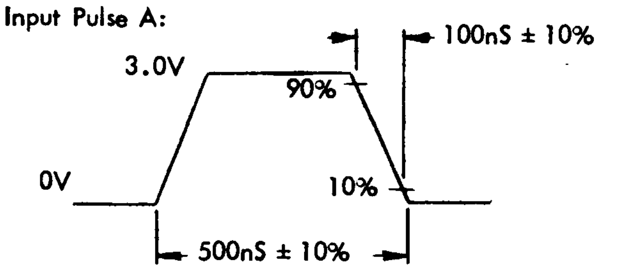
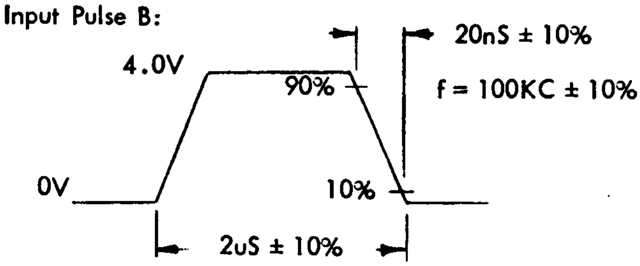
CODE IDENT NO. 76301







CLOCKED MODE SWITCHING LEVEL

Procedure:

a) Set V_9=1.0 Vdc; V_2=4.0 Vdc; momentary contact, V_7 to ground.
b) Apply one input pulse to Pin 10.
c) The device shall be rejected if it does not change state when the single input pulse is applied.
d) Set V_9=4.0 Vdc; V_2=1.0 Vdc; momentary contact, V_4 to ground.
e) Apply one input pulse to Pin 10.
f) The device shall be rejected if it does not change state when the single input pulse is applied.

CLOCKED MODE HOLDING LEVEL

a) Apply input pulses.
b) Set V_2=3.4V, V_9=4.0V.
c) Momentary contact, Pin 4 to Pin 1, V_8 shall be high ($>$ 3.5V).
d) The part shall be rejected if V_8 does not remain high when Pin 4 is open.
e) Set V_2=4.0V, V_9=3.4V.
f) Momentary contact, Pin 7 to Pin 1, V_8 shall be low ($<$ 0.5V).
g) The part shall be rejected if V_8 does not remain low when Pin 7 is open.

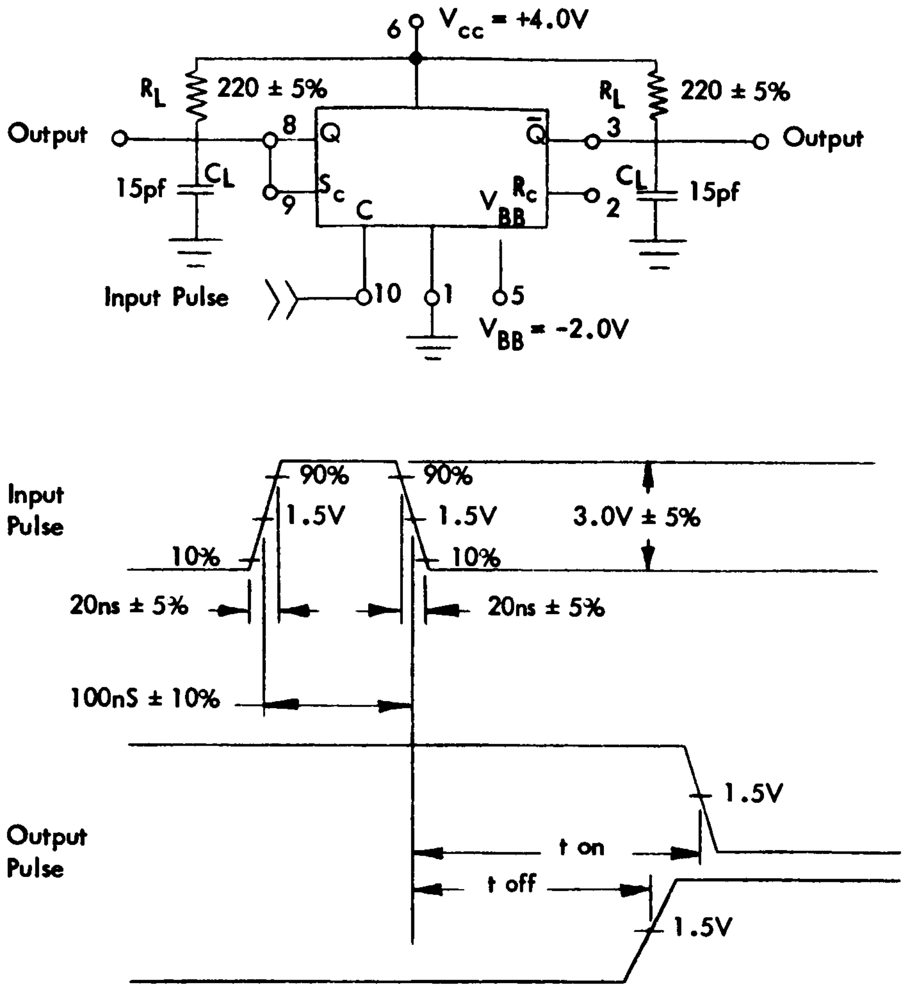
FIGURE 1

DRAWN		APPRD			INTEGRATED CIRCUIT FLIP FLOP, RST	REV	MODEL	VOL	ASSY NO.
CHECK		APPRD							
APPRD		APPRD			MCDONNELL ST. LOUIS, MO.	DRAWING NO. 207-780007			SHEET 12

REVISED:

MAC 1202A (REV 4 AUG 61)

CODE IDENT NO. 76301



Note:
C_L includes jig and probe capacitance

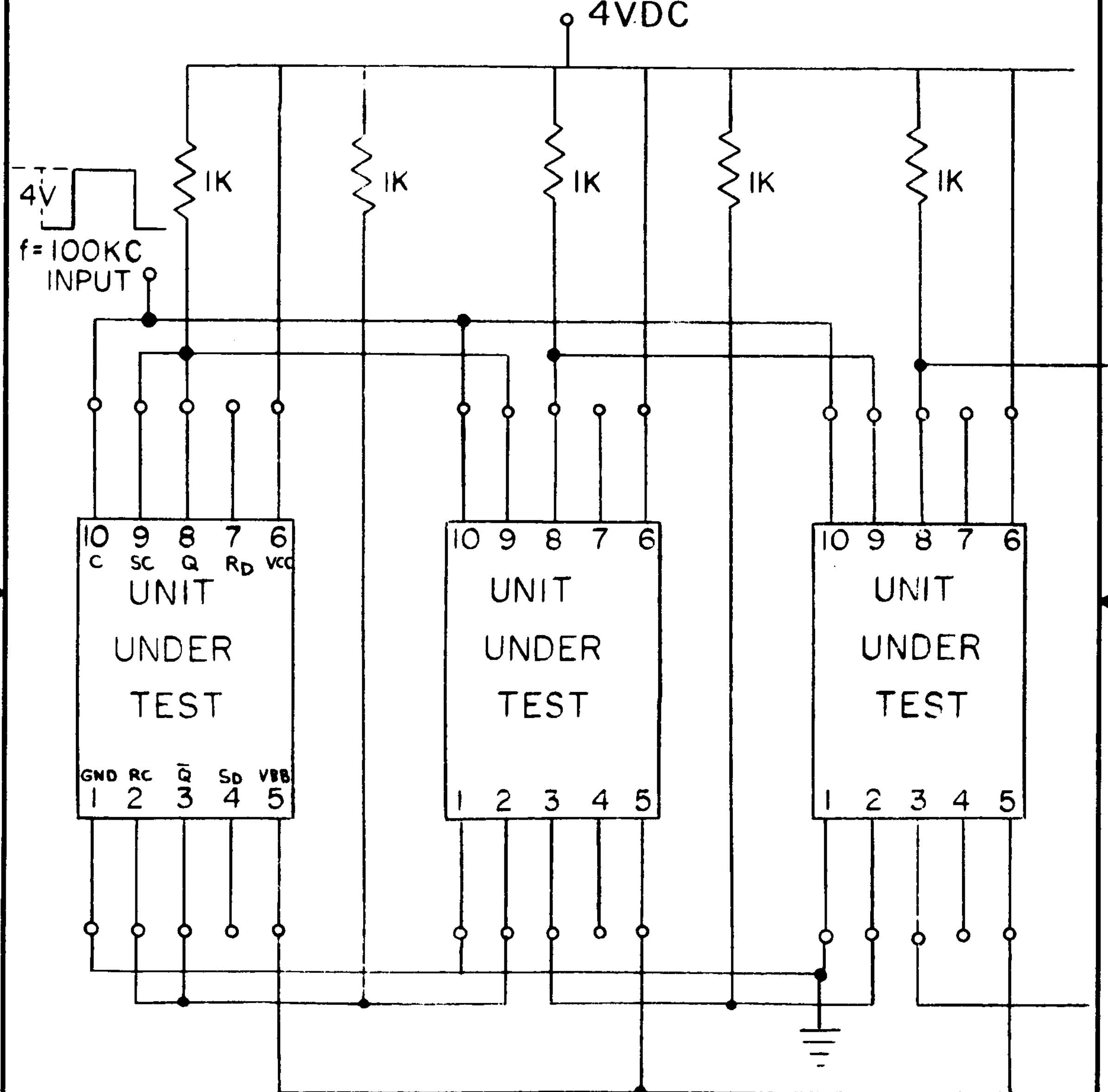
SWITCHING TIME TEST CIRCUIT
FIGURE 2

DRAWN			APPRD			INTEGRATED CIRCUIT FLIP FLOP, RST	REV	MODEL	VOL	ASSY NO.
CHECK			APPRD							
APPRD			APPRD			MCDONNELL ST. LOUIS, MO.	DRAWING NO. 207-780007			SHEET 13

REVISED:

MAC 1202A (REV 4 AUG 61)

CODE IDENT NO. 76301



DYNAMIC OPERATING CIRCUIT
(POWER BURN IN AND OPERATING LIFE)
FIGURE 3

DRAWN			APPRD			INTEGRATED CIRCUIT FLIP FLOP, RST	REV	MODEL	VOL	ASSY NO.
CHECK			APPRD							
APPRD			APPRD			MCDONNELL ST. LOUIS, MO.	DRAWING NO. 207-780007			SHEET 14

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Parts shall be procured directly from the manufacturers listed under the following approved sources of supply:

Signetics Corporation (18324)
Sunnyvale, California

Part No. SE124G

The above listed vendors and designations are the only items and sources for parts specified herein approved for procurement and/or use on McDonnell products. Vendors of competitive articles may apply to the McDonnell Standards Engineering Department for approval as a source of supply.

DRAWN		APPRD			INTEGRATED CIRCUIT FLIP FLOP, RST	REV	MODEL	VOL	ASSY NO.
CHECK		APPRD							
APPRD		APPRD			MCDONNELL ST. LOUIS, MO.	DRAWING NO. 207-780007			SHEET 15

REVISED:

MAC 1202A (REV 4 AUG 61)

CODE IDENT NO. 76301